AD-A052 478 CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT F/G 6/6
CHESAPEAKE BAY FUTURE CONDITIONS REPORT. VOLUME 8. NAVIGATION, --ETC(U)
DEC 77

UNCLASSIFIED FCR-77-008 NL

1 OF 5
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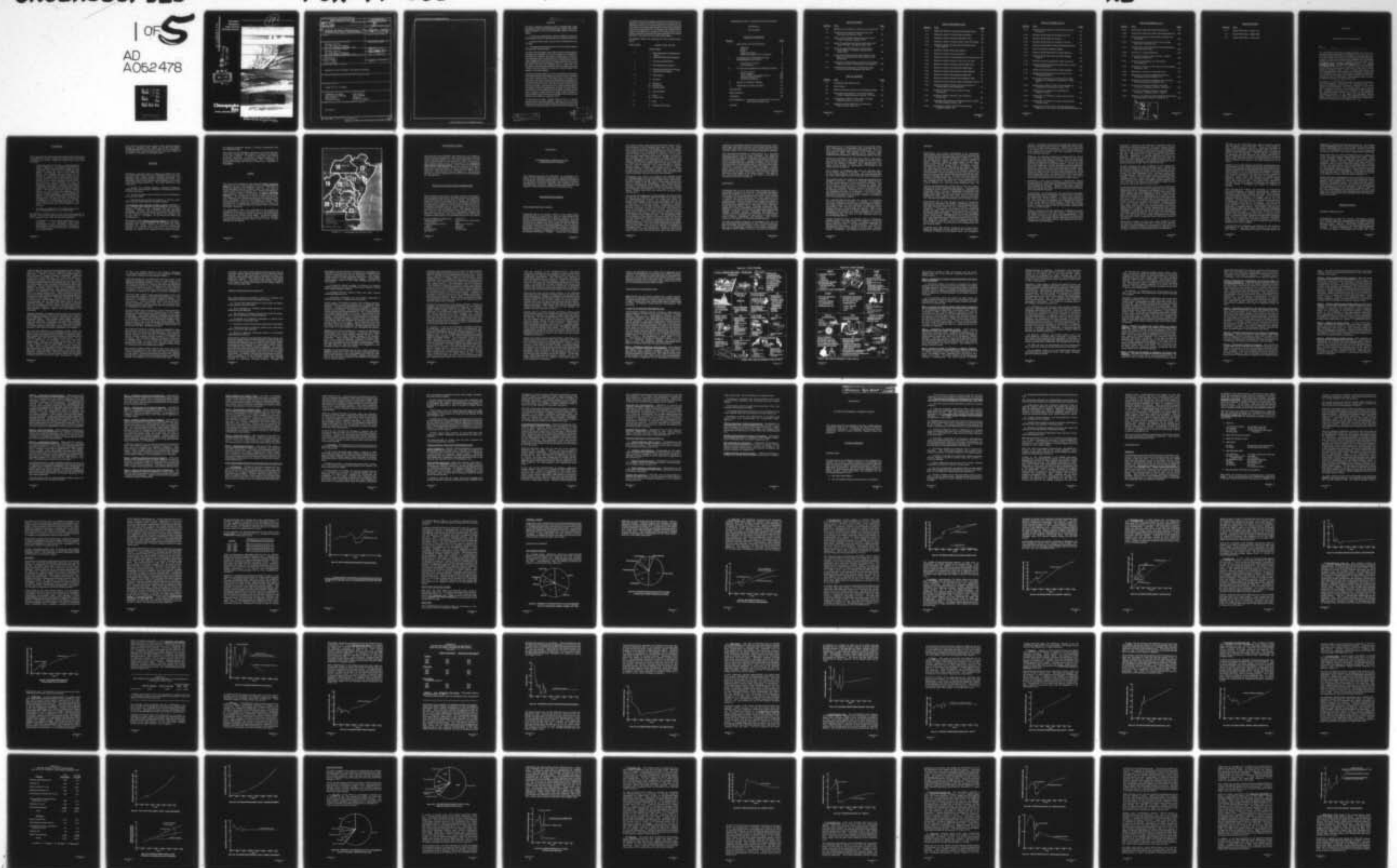

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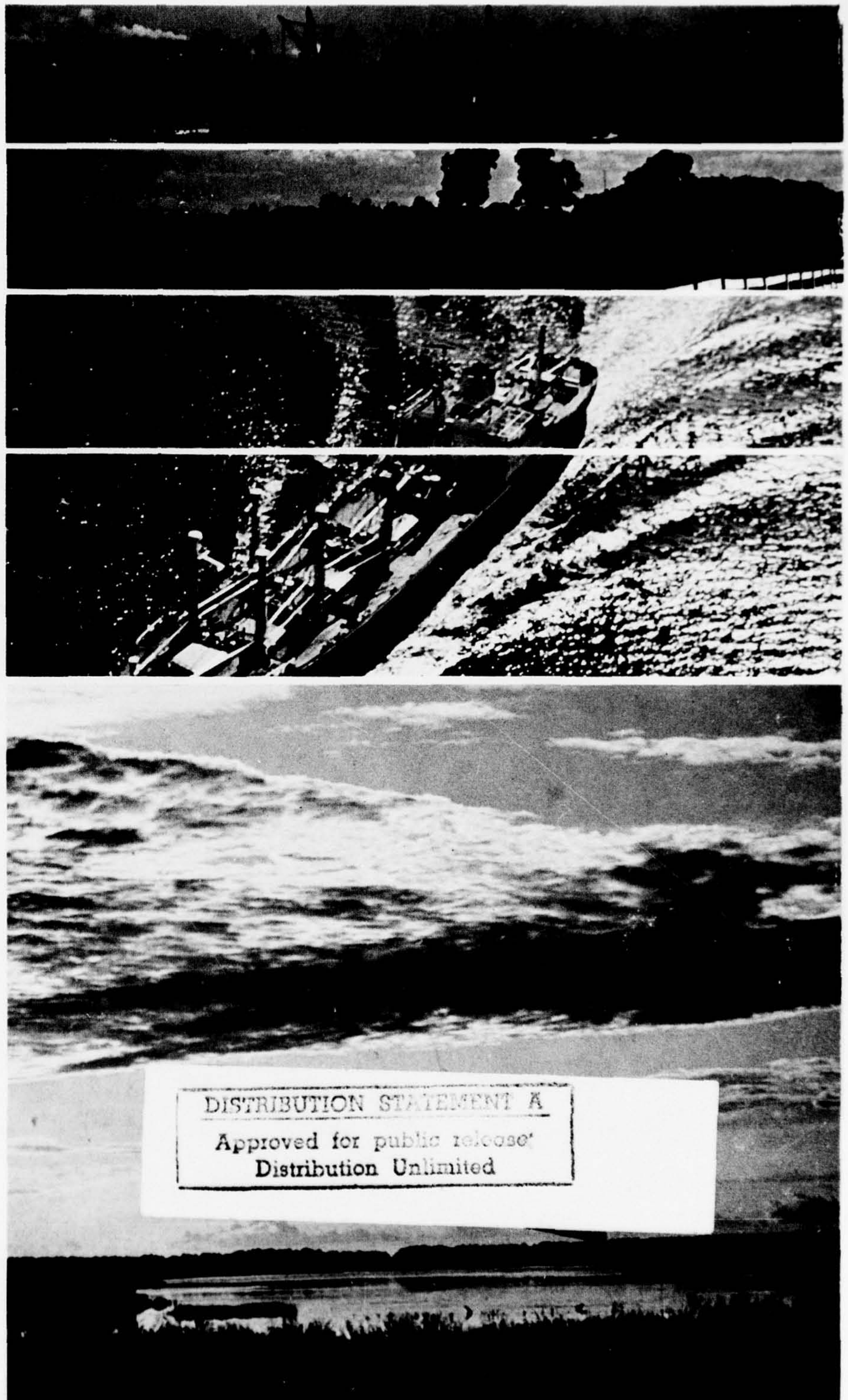
AD A052478

VOLUME 8
Navigation, Flood Control, Shoreline Erosion



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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 14 FCR-77-008
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER: 9
4. TITLE (and Subtitle): 6 Chesapeake Bay Future Conditions Report: Volume 8. Navigation, Flood Control, Shoreline Erosion.
5. TYPE OF REPORT & PERIOD COVERED: INTERIM rept.
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)
8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS

   Baltimore District
   U.S. Army Corps of Engineers
   Box 1715, Baltimore, Maryland 21203
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS

    Baltimore District
    U.S. Army Corps of Engineers
    Box 1715, Baltimore, Maryland 21203
12. REPORT DATE: 11 Dec[redacted]77
13. NUMBER OF PAGES: 370
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 399p.
15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

    Approved for Public Release, distribution unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES

    Volume VIII of 12 Volumes
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Chesapeake Bay Region	Flood Control
Water Resources Planning	Tidal Flooding
Beach Erosion	Navigation
Shoreline Erosion	Waterborne Commerce

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

    See Preface

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

The Corps of Engineers' comprehensive study of Chesapeake Bay is being accomplished in three distinct developmental stages or phases. Each of these phases is responsive to one of the following stated objectives of the study program.

1. To assess the existing physical, chemical, biological, economic and environmental conditions of Chesapeake Bay and its related land resources.

2. To project the future water resources needs of Chesapeake Bay to the year 2020.

3. To formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

In response to the first objective of the study, the initial or inventory phase of the program was completed in 1973 and the findings were published in a document titled *Chesapeake Bay Existing Conditions Report.* Included in this seven-volume report is a description of the existing physical, economic, social, biological and environmental conditions of Chesapeake Bay. This was the first published report that presented a comprehensive survey of the entire Bay Region and treated the Chesapeake Bay as a single entity. Most importantly, the report contains the historical records and basic data required to project the future demands on the Bay and to assess the ability of the resource to meet those demands.

In response to the second objective of the study, the findings of the second or future projections phase of the program are provided in this the *Chesapeake Bay Future Conditions Report.* The primary focus of this report is the projection of water resources needs to the year 2020 and the identification of the problems and conflicts which would result from the unrestrained growth and use of the Bay's resources. This report, therefore, provides the basic information necessary to proceed into the next or plan formulation phase of the program. It should be emphasized that, by design, this report addresses only the water resources related needs and problems. No attempt has been made to identify or analyze solutions to specific problems. Solutions to priority problems will be evaluated in the third phase of the program and the findings will be published in subsequent reports.

The *Chesapeake Bay Future Conditions Report* consists of a summary document and 16 supporting appendices. Appendices 1 and 2 are general background documents containing information describing the history and conduct of the study and the manner in which the study was coordinated with

the various Federal and State agencies, scientific institutions and the public. Appendices 3 through 15 each contain information on specific water and related land resource uses to include an inventory of the present status and expected future needs and problems. Appendix 16 focuses on the formulation of the initial testing program for the Chesapeake Bay Hydraulic Model. Included in this appendix is a description of the hydraulic model, a list of problems considered for inclusion in the initial testing program and a detailed description of the selected first year model studies program.

The published volumes of the *Chesapeake Bay Future Conditions Report* include:

Volume Number	*Appendix Number and Title*
1	Summary Report
2	1 — Study Organization, Coordination and History 2 — Public Participation and Information
3	3 — Economic and Social Profile
4	4 — Water-Related Land Resources
5	5 — Municipal and Industrial Water Supply 6 — Agricultural Water Supply
6	7 — Water Quality
7	8 — Recreation
8	9 — Navigation 10 — Flood Control 11 — Shoreline Erosion
9	12 — Fish and Wildlife
10	13 — Power 14 — Noxious Weeds
11	15 — Biota
12	16 — Hydraulic Model Testing

CHESAPEAKE BAY FUTURE CONDITIONS REPORT

APPENDIX 9

NAVIGATION

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CHAPTER I

THE STUDY AND THE REPORT

Volume 9 consists of 3 appendices.

The Chesapeake Bay Study developed through the need for a complete and comprehensive investigation of the use and control of the water and related land resources of Chesapeake Bay. In the first phase of the study, the existing physical, biological, economic, social and environmental conditions and the present problem areas in the Bay were identified and presented in the Chesapeake Bay Existing Conditions Report. The Future Conditions Report, of which this appendix is a part, presents the findings of the second or projections phase of the study. As part of this second phase of the study, projections of future needs and problem areas, means to satisfy those needs, and recommendations for future studies and hydraulic model testing were developed for each of the resource categories evaluated. The results of this phase of the study constitute the next step toward the goal of developing a comprehensive water resource management program for Chesapeake Bay.

The subject of this volume, Appendix 9, Navigation, focuses on the importance of waterborne commerce to the Chesapeake Bay. The historical significance of waterborne commerce to the development of the Bay Region, the present levels of use of the Bay's waterways and some of the navigation-related problems and conflicts are discussed and identified ~~in this appendix~~. The appendix further presents the results of projections of waterborne commerce in the Region and identifies possible future problem areas. Lastly, this appendix identifies future studies required to meet the goal of developing a management plan for the resources of Chesapeake Bay. (cont on p. 1 Appendix 10)

AUTHORITY

The authority for the Chesapeake Bay Study and the construction of the hydraulic model is contained in Section 312 of the River and Harbor Act of 1965, adopted 27 October 1965, which reads as follows:

> (a) The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a complete investigation and study of water utilization and control of the Chesapeake Bay Basin, including the waters of the Baltimore Harbor and including, but not limited to, .the following: navigation, fisheries, flood control, control of noxious weeds, water pollution, water quality control, beach erosion, and recreation. In order to carry out the purposes of this section, the Secretary, acting through the Chief of Engineers, shall contruct, operate, and maintain in the State of Maryland a hydraulic model of the Chesapeake Bay Basin and associated technical center. Such model and center may be utilized, subject to such terms and conditions as the Secretary deems necessary, by any department, agency, or instrumentality of the Federal Government or of the States of Maryland, Virginia, and Pennsylvania, in connection with any research, investigation, or study being carried on by them of any aspect of the Chespeake Bay Basin. The study authorized by this section shall be given priority.
>
> (b) There is authorized to be appropriated not to exceed $6,000,000 to carry out this section.

An additional appropriation for the study was provided in Section 3 of the River Basin Monetary Authorization Act of 1970, adopted 19 June 1970, which reads as follows:

> In addition to the previous authorization, the completion of the Chesapeake Bay Basin Comprehensive Study, Maryland, Virginia, and Pennsylvania, authorized by the River and Harbor Act of 1965 is hereby authorized at an estimated cost of $9,000,000.

As a result of Tropical Storm Agnes, which caused extensive damage in Chesapeake Bay, Public Law 92-607, the Supplemental Appropriation Act of 1973, signed by the President on 31 October 1972, included $275,000 for additional studies of the impact of the storm on Chesapeake Bay.

PURPOSE

Previously, measures taken to utilize and control the water and land related resources of the Chesapeake Bay Basin have generally been toward solving individual problems. The Chesapeake Bay Study provides a comprehensive study of the entire Bay Area in order that the most beneficial use be made of the water-related resources. The major objectives of the Study are to:

a. Assess the existing physical, chemical, biological, economic and environmental conditions of Chesapeake Bay and its water resources.

b. Project the future water resources needs of Chesapeake Bay to the year 2020.

c. Formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

The Chesapeake Bay Existing Conditions Report, published in 1973, met the first objective of the study by presenting a detailed inventory of the Chesapeake Bay and its water resources. Divided into a summary and four supporting appendixes, the report presented an overview of the Bay area and the economy; a survey of the Bay's land resource and its use; and a description of the Bay's life forms and hydrodynamics.

The purpose of the Future Conditions Report is to provide a format for presenting the findings of the Chesapeake Bay Study. Satisfying the second objective of the Study, the report describes the present use of the resource, presents the demands to be placed on the resource to the year 2020, assesses the ability of the resource to meet future demands,

and identifies additional studies to develop a management plan for Chesapeake Bay.

The purpose of this Navigation Appendix is to present the findings of the Chesapeake Bay Study as it relates to navigation in the Bay's waters. It should be noted that this volume primarily addresses commercial navigation problems and needs rather than recreational boating. For a discussion of recreational boating, the reader is referred to Appendix 8: Recreation.

SCOPE

The scope of the Chesapeake Bay Study and Future Conditions Report includes the multi-disciplinary fields of engineering and the social, physical, and biological sciences. The study is being coordinated with all Federal, State, and local agencies having an interest in Chesapeake Bay. Studied subregionally, each resource category presented in the Future Conditions Report projects demands and potential problem areas to the year 2020. All conclusions are based on historical information supplied by the preparing agencies having expertise in that field. In addition, the basic assumptions and methodologies are quantified for accuracy in the sensitivity section. Only general means to satisfy the projected resource needs are presented, as recommendations for specific areas are beyond the scope of the Study.

The geographical study area considered in the analysis of waterborne commerce is consistent with the Chesapeake Bay Estuary Area as defined for the economics and demographic projections made for the overall Study. As shown on Figure 9-1, the study area encompasses those counties or Standard Metropolitan Statistical Areas which touch or have a major influence on the Estuary.

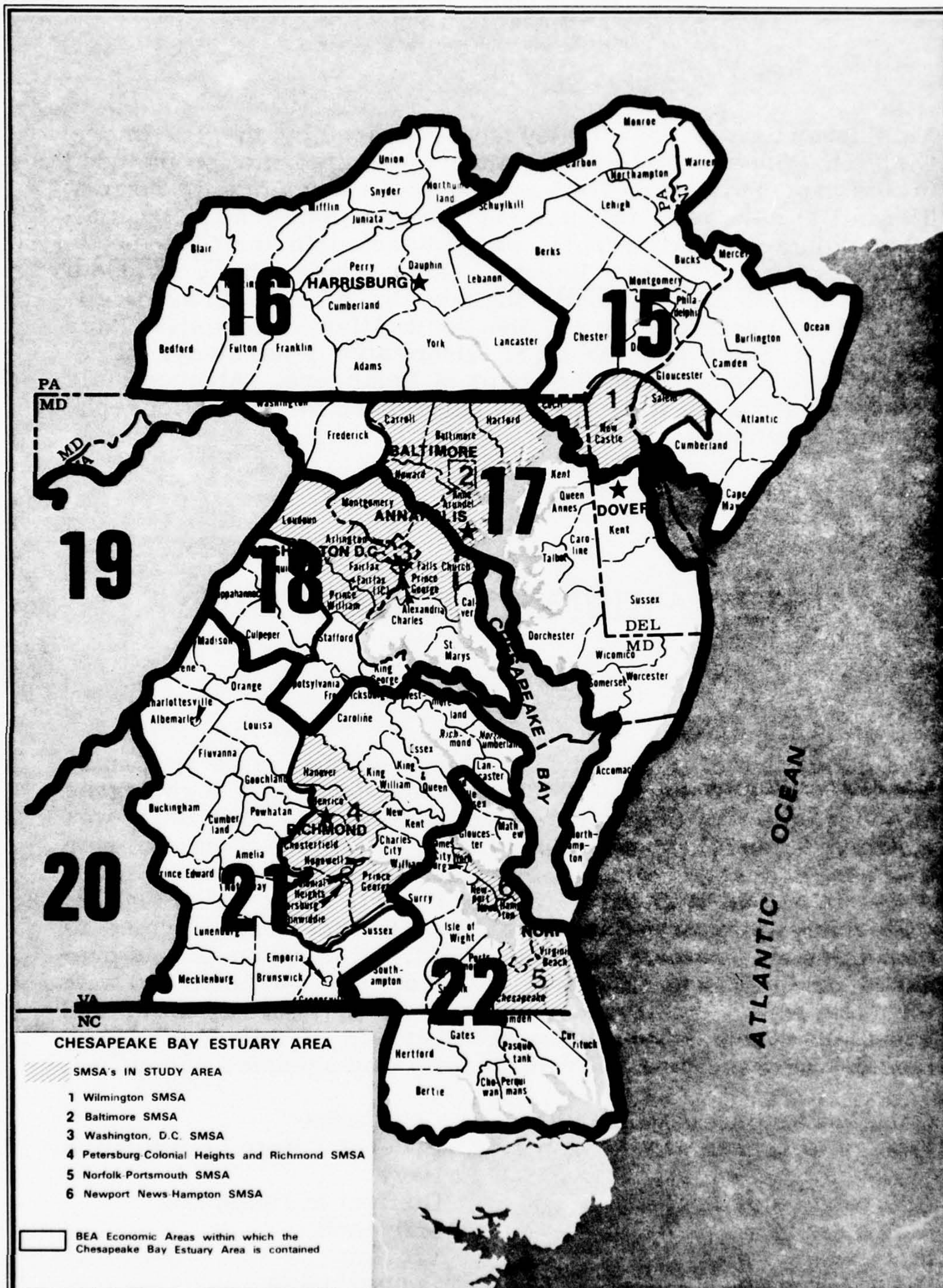


FIGURE 9-1: Chesapeake Bay Estuary Area

SUPPORTING STUDIES

This appendix was coordinated and prepared by the Baltimore District, Corps of Engineers. Much of the information included in this report was taken from or developed using other sources. The initial data base for this particular volume, as well as all other volumes of this report, was presented in the Chesapeake Bay Existing Conditions Report. Other studies that provided a major input to this appendix include the Atlantic Coast Deepwater Port Facilities Study, the North Atlantic Regional Water Resources Study and the U. S. Deepwater Port Study, all of which were conducted by the Corps of Engineers. All materials and data used in the appendix are referenced in the Bibliography for this appendix.

STUDY PARTICIPANTS AND COORDINATION

The magnitude of this study, the large number of participants, and the complex spectrum of problems requires a high degree of coordination of the various study activities. This Study was conceived and has developed as a coordinated partnership between Federal, State and interested educational institutions. As explained in Appendix 1 of this report, an Advisory Group, a Steering Committee and five Task Groups were formed to coordinate and review the study effort. This appendix was prepared by the Corps of Engineers under the guidance and with the review of the Flood Control, Navigation, Erosion and Fisheries Task Group. The membership of this Task Group includes representatives from the following agencies and states:

Corps of Engineers (Chairman)
Energy Research and Development
Environmental Protection Agency
Interior
Transportation
Agriculture
Commerce
Federal Power Commission
Navy
District of Columbia
Maryland
Virginia
Pennsylvania

CHAPTER II

WATERBORNE COMMERCE IN THE CHESAPEAKE BAY REGION

This chapter describes the importance of waterborne commerce to the Chesapeake Bay Region. More specifically, it discusses the historical significance of waterborne commerce to the Region, describes the present levels of use of the Bay's waterways by commercial interests, and identifies some of the waterborne commerce related problems and conflicts with respect to other resources and uses of Chesapeake Bay.

DESCRIPTION OF REGION

THE CHESAPEAKE BAY REGION

Chesapeake Bay is the largest estuary in the United States stretching south 195 miles from near the Pennsylvania line almost to North Carolina with a maximum width of 30 miles near the Maryland-Virginia line. More importantly, from the standpoint of navigation, the Bay has countless tidal tributaries, some of which extend many miles inland on both the Eastern and Western Shores to important metropolitan areas serving as production, consumption, and distribution centers. The largest metropolitan areas are located on the Western Shore and include Baltimore, Maryland; Washington, D.C.; Richmond, Virginia; and Norfolk-Portsmouth, Virginia. These four metropolitan

areas alone contained approximately 90 percent of the 7.9 million inhabitants of the Chesapeake Bay Region in 1970. These areas (with the exception of Washington D.C.) are also important manufacturing centers employing approximately 82 percent of the Region's total manufacturing workers. Many of these jobs are related, either directly or indirectly, to the area's water-based transportation system. For example, according to the Maryland Port Authority (MPA), 65,000 workers are directly employed by port activities in the Baltimore area and another 100,000 in port-related industries.(1) A similar study in Virginia for all the Virginia ports revealed that 31,000 people were directly employed in the Commonwealth of Virginia by port-related activities and another 77,000 by "harbor-oriented activities" including naval installations.(2) It should be noted that both of the above studies were concerned with foreign commerce only and that the totals would be significantly larger if domestic commerce had also been included.

Chesapeake Bay, due to its origin as the drowned mouth of the Susquehanna River and its location on the Coastal Plain, is relatively shallow having a mean depth of less than 28 feet. Down the middle of the Bay runs a much deeper channel--the ancient riverbed of the Susquehanna. This channel provides the major thoroughfare for the large tankers, bulk carriers, freighters, and containerships visiting the Bay ports between the Chesapeake and Delaware (C & D) Canal and the Atlantic Ocean. Natural deep water also extends far up many of the sub-estuaries.

The geology and topography of the Chesapeake Bay Region make the Bay and its tributaries highly susceptible to the processes of sedimentation and erosion. On a long term basis, the natural sedimentation process in the Chesapeake Bay and its tributaries is tending to fill the estuarine system and convert it, once again, to a riverine system. Deposition of sediment generally occurs in the upper reaches of tidal influence where the river flow slows and the salt and fresh water interact to cause the sediments to settle to the bottom. In this manner, much of the estimated 2.5 million tons of sediment per year discharged by the Potomac River into the Estuary is trapped in the estuary of the tributary itself. The Susquehanna River is an exception to this general rule since it flows directly into the Bay and deposits between 0.3 and 0.9 million tons of sediment per year. As a result, sedimentation rates are proportionally greater at the head of the Bay proper than in the middle and lower portions. The most critical sedimentation problems exist in those tributaries which are adjacent to urbanized or developing areas. In these places, because of construction activities and increased runoff rates, sediment yields range from 1,000 to over 100,000 tons per square mile per year as

compared to undeveloped areas where annual yields per square mile range from 200 to 500 tons. In the middle and lower portions of the Bay proper shore erosion, caused mainly by waves and tidal action, is one of the principal sources of sediment.

The Chesapeake Bay Region is characterized by a generally temperate climate with no major extremes. The relatively mild temperatures make the freezing of the Bay's harbors an extremely rare occurrence. Tides and currents are also moderate in Chesapeake Bay. Average maximum tidal velocities in mid-channel of the Bay range from 0.5 knots to over 2 knots. The mean range of tides varies from 2.8 feet at the Cape Henry Channel to 1.1 at Fort McHenry in Baltimore Harbor. In addition to the oscillatory tidal current is a non-tidal circulation pattern which is characterized by a seaward flow of relatively fresh water in the upper layers and a flow of saltier seawater directed up the estuary in the deeper layers. The speed of this net non-tidal flow is only on the order of one-fifth the magnitude of the tidal currents. (3)

RESOURCES

Chesapeake Bay is one of the most highly biologically productive estuarine systems in the world. Commercial landings of finfish and shellfish in the Bay in 1970 totaled 630 million with a dock value of approximately $41 million. Sport landings of shellfish and finfish during the year were estimated to be as large as the commercial harvest. The Bay also serves as a spawning and nursery ground for fish caught from Maine to North Carolina. Several studies of the migration patterns of the striped bass indicate that at least half of the "stripers" caught along the Atlantic Coast, excluding Chesapeake Bay, originated in the Chesapeake's waters. (4) Some of the other fish that use the Bay as a nursery or spawning ground include weakfish, herring, croaker, menhaden, and kingfish. In addition, the Bay's wetlands and tidewater woodlands support a wide variety of waterfowl and other birds, as well as many types of reptiles, amphibians, and mammals. Some of these animals in turn support an important hunting industry.

The fish and wildlife resources of Chesapeake Bay are not spread homogenously throughout the area. The most productive parts of the Bay are those areas of low salinity in the upper Bay and corresponding portions of the major tributaries. Although the entire estuary serves as a nursery area for finfish,

spawning areas are concentrated in these low salinity areas. The northern part of Chesapeake Bay, including the C & D Canal, is probably the largest of all spawning areas. This area area plus the upper tidal portions of the Potomac, York, Rappahannock, James, and Patuxent Rivers represent about 90 percent of the anadromous fish spawning grounds in the Bay.

Oysters are abundant in many parts of the estuary. The numerous small bays, coves, and inlets along the Eastern Shore between the Chester and Nanticoke Rivers and the lower portions of the Patuxent, Potomac, York, Rappahannock, and James Rivers account for approximately 90 percent of the annual harvest of oysters.

Some species of Chesapeake Bay fish and shellfish thrive in the saltier waters of the Estuary. The mouth of the Bay, an area of high salinity, is the major blue crab spawning area for most of the crabs harvested in the Bay and its tributaries.

The wetlands of the Bay Region are especially important in the biological ecosystem. Most of the important finfish found in the Bay spend at least part of their lives in the wetlands. They serve as great "protein farms" converting the energy from the sun into protein energy in a form usable by the aquatic community. The wetlands, therefore, serve as a primary link in the estuary's food chain. Wetland areas are scattered throughout Chesapeake Bay and its tributaries. The largest single concentration of wetlands in the Region, by far, is located in Somerset, Dorchester, and Accomack counties on the Eastern Shore of Maryland and Virginia.

The important thing to note about the ecology of Chesapeake Bay is the fragility of the system. In general, the ecology of an estuary is usually characterized by an abundance of individuals within species but with relatively few different species represented. The diversity often found in other types of ecosystems provides a certain buffering capacity. Where many alternatives are possible, the loss or elimination of a few is insignificant. When diversity is relatively slight, as in the case of Chesapeake Bay, the loss of a few component parts can have devastating effects.

Besides Chesapeake Bay's recreational value as a fishing and hunting resource, the Bay also provides millions of recreation days of sailing, swimming, boating, picnicking, camping, and nature study each year. The approximately 7,300 miles of shoreline and 4,400 square miles of surface area have the potential for expanded recreational use in the future, provided certain institutional and biological problems are overcome.

HISTORY

Historically, the economic development of the Chesapeake Bay Region has been largely based on the natural transportation network provided by Chesapeake Bay and its tributaries. During the colonial period, when the production of tobacco dominated the economy of the Region, the Bay's extensive network of natural waterways opened-up approximately 10,000 square miles of tidewater land to immediate cultivation. In 1660, approximately 80,000 people lived in the English colonies, two-thirds of these in the Chesapeake Bay Region. Despite the large influx of people before the Revolutionary War, there was little inclination on the part of the Region's colonists to settle into towns. In an environment in which each planter could load his crops on ships which could dock almost at his doorstep, towns were simply not needed. "No land is bettered watered," wrote the Reverend Hugh Jones in 1724, "for the conveniency of which most houses are built near some landing place; so that anything may be delivered to a gentleman there from London, Bristol, etc., with very little trouble and cost." (5)

Both the Revolutionary War and the War of 1812 had significant impacts on the Chesapeake Bay Region. The young town of Baltimore enjoyed quite a shipbuilding and outfitting boom during both wars. The town's shipbuilders outfitted the first frigate of the Continental Navy, and the first two cruisers of the United States Navy. On the other hand, the town of Norfolk, probably the most important town in the Region at the time, was destroyed during the Revolutionary War by British troops.

Following the War of 1812, the great process of urbanization began in the Chesapeake Bay Region. Settlement moved westward past the Fall Line and into the fertile Piedmont Plateau. The towns along the Fall Line (e.g. Baltimore, Richmond, Alexandria, Georgetown, Petersburg, and Fredricksburg) quickly developed into marketing and processing centers for the produce of the hinterlands. The produce was then shipped from these towns on oceangoing vessels to the major population centers of the world. The individual rates of growth of these port towns depended on the productivity and extent of the hinterland which each controlled. The towns began projects which were designed to increase the area of hinterland which they served and to improve the efficiency of the transportation system from the West.

During the early 19th century, Richmond on the James River, along with Alexandria and Georgetown on the Potomac River, embarked on ambitious canal projects which were designed to

capture a large share of the fast-developing Ohio River trade. The time and expense involved in the construction of these projects were woefully underestimated. Political bickering added to the delays and costs and eventually some of the canals were made obsolete even before they were completed by faster, more efficient railroads.

Baltimore was probably fortunate in being located on a river which did not reach very far inland. The city did not get caught-up in the canal building era which swept the East Coast. Instead, construction was begun in 1827 on one of the first commercial railroads in the United States. In 1842, the main line of the Baltimore and Ohio Railroad reached Cumberland, Maryland, eight years before the Chesapeake and Ohio Canal. By the time the railroad reached the Ohio River in 1852, Baltimore had become one of the major ports in the Nation. In the Census of 1840, the City was the second largest in the United States behind New York. The failure of the C & O Canal effectively eliminated the ports on the Potomac River as serious competitors to Baltimore for the trade of the Ohio Valley.

Meanwhile, a race was developing in southeastern Virginia between Norfolk, Richmond, and Petersburg for control of the profitable tobacco trade of the Roanoke River Valley, traditionally controlled by Norfolk. Richmond ultimately gained the upper hand during the 1850's with the construction of the Richmond and Danville Railroad.

Improvements in transportation and agricultural technology stimulated the further development of the raw material industries throughout the Bay Region. A wheat boom, starting in the 1820's, gave added impetus to the flour-milling business. By 1830, Maryland and Virginia were producing over one-half of the wheat raised in North America. Baltimore and Richmond vied for the title of the country's major flour-milling center. During the period 1834-50, Richmond's Gallego Mills were the world's largest.

Tobacco production and processing also continued to increase during the first half of the 19th century. Richmond became the Nation's center for the tobacco processing industry. The city alone processed more tobacco than New York, the second ranking state. Concurrent with the expansion of tobacco processing, the cotton milling industry also expanded in the cities of Richmond and Petersburg.

Meanwhile, Baltimore was following a different course of economic and social development. The city's economy became much more diversified after the Revolution, relying less on tobacco for its well-being. Commercial ties were established with the newly formed South American republics and China. The port developed into a major importer for guano from Peru for distribution to Southern plantations for use as a fertilizer. Coffee from Brazil and copper ore from Chile and Peru were also important in the South American trade. In sharp contrast to Richmond and Petersburg, Baltimore developed an important middle class of skilled workers.

By 1860, Baltimore was well established as the leading commercial and industrial center in the Bay Area. Norfolk had not grown as rapidly as the other cities in the Region because of its failure to establish strong commercial ties with the hinterland. By 1860, Washington, D.C., had begun to show signs of awakening from its 60-year slumber since its establishment, although United States Senators and Representatives often complained of cows, sheep, and goats roaming through the city's unimproved streets. Washington's modest growth, however, was due to its function as the Nation's capital and not to any success by the city as a trade center.

Of interest during the pre-Civil War period were several navigation improvement projects which turned out to be successful. Construction of the Chesapeake and Delaware (C & D) Canal which connects the Chesapeake and Delaware Bays across the upper Eastern Shore was completed in 1829. It shortened the route from Baltimore to Philadelphia by 316 miles, to New York by 179 miles, and to European ports by about 100 miles. The canal is still in operation and it annually handles over 20,000 vessels of all types (including recreational) making it one of the busiest waterways in the world. Another project took place around 1800 in the young town of Baltimore whose docks were separated from natural deepwater by several hundred feet of swamp. Several businessmen took it upon themselves to dredge the mud and silt from the basin bottom, excavating a ship channel and at the same time extending the pier to the edge of the channel. This venture was so successful that a tax was levied on all vessels entering the port and the proceeds were used to dredge the harbor and fill the surrounding marsh.

Baltimore's maritime activities once again prospered under war contracts during the Civil War. To the south, however, the story was quite different. Vast amounts of crops were confiscated or destroyed; plantation buildings were burned; and the railways, factories, and port facilities were in shambles.

The cities in the Chesapeake Bay Region recovered quickly from the effects of the Civil War, due to a large degree to their excellent deepwater harbors. Baltimore continued to improve its connections with the Midwest after the War by double-tracking the line west and obtaining good rail connections with St. Louis and Chicago. John B. Garrett, president of the Baltimore and Ohio Railroad, who heavily committed his firm to exporting farm products through Baltimore, predicted that the Port would become the "Liverpool of America". (6) In 1876, Baltimore was ranked as the sixth largest port in the world.

Further to the south, Norfolk was likewise being transformed. Consolidation of many small railroads into what finally became known as the Norfolk and Western Railroad allowed commerce, which previously went to Richmond for processing and/or shipment overseas, to be be channeled toward Norfolk. Although a great variety of products have helped in the port's expansion, from 1885 to the present coal has been the leading item in Norfolk's export trade. The Norfolk and Western pushed branch lines up all the narrow mountain valleys in Virginia where coal could be found. This railroad then extended its trackage into the West Virginia and Kentucky coal regions and thereby secured a continuous coal supply for shipment to Norfolk.

After the turn of the century, the processes of urbanization and industrialization accelerated tremendously. Along the shorelines of Baltimore, Norfolk, Richmond, and other cities of the Bay Region large factories were built. Many different factors attracted industries to the Region, one of the most important being the existence of excellent harbors and port facilities. Two different groups of industries were attracted to Chesapeake Bay cities for this reason. The first group is the industries which located at deepwater sites because of their need for a cheap form of transportation either for raw materials or finished products. For example, the Maryland Steel Company (later the Sparrows Point plant of the Bethlehem Steel Corporation) opened a large plant in Baltimore to refine imported ore from Cuba. In 1920, what is now one of the largest sugar refining plants in the world was opened in Baltimore. In addition, plants throughout the Bay Region producing such items as electrical goods and machinery, fertilizers, plaster and plasterboard, industrial chemicals, petroleum products, and refined copper, use Chesapeake Bay and its tributaries for water transport.

A second group of industries was attracted by the maritime environment of the Bay Region because of the nature of their product. Shipbuilding activities in Hampton Roads and

Baltimore are examples of this type of industry. The Newport News Shipbuilding and Dry Dock Company is one of the largest private shipbuilding firms in the world. Related to this last factor is the acquisition by the Navy in 1917 of a large tract of land for what is now the world's largest Naval installation.

Since World War II, several developments have significantly altered the import-export trade along the East Coast. First, the St. Lawrence Seaway, talked about for decades, finally came into being in 1956 and siphoned significant quantities of import iron ore and export grain away from the Port of Baltimore, and to a lesser extent the Hampton Roads complex. Second, the United States Steel Corporation elected to build its first tidewater plant at Fairless on the Delaware River and the Pennsylvania Railroad built a large import ore terminal on the Delaware below Philadelphia. These last two developments had the effect of diverting large shipments of iron ore from Baltimore to these Delaware River terminals. (7)

Despite the above developments and the resultant diversion of bulk grain and ore shipments away from Chesapeake Bay ports, general cargo tonnages have shown steady increases at both Baltimore and Hampton Roads. The trend toward the containerization of general cargo has necessitated the expenditure of many millions of dollars by both ports on special equipment and land acquisition in order to handle container traffic. In the case of both Baltimore and Hampton Roads, however, these costs have been justified since both ports have increased their share of the total general cargo tonnage of the East Coast during the last decade.

PRESENT STATUS

PRESENT RESOURCE USE

Transportation by water has become increasingly complex since colonial times when oceangoing 500-ton sailing ships with 10 to 15-foot drafts plied the Chesapeake docking at individual plantation piers. However, water-based transportation has remained extremely important to the Chesapeake Bay Region's economy. A total of approximately 150 million short tons of cargo was shipped on Chesapeake Bay during 1970. Most

of this freight (82 percent) passed through the ports of Baltimore (51 million short tons) or Hampton Roads (71 million short tons). About 70 percent of the total freight traffic in these two ports is foreign in origin or destination. Baltimore is basically an importing port. The major commodities on a weight basis coming into Baltimore are iron ore, copper, aluminum, manganese, and other nonferrous ores and concentrates, petroleum and petroleum products, gypsum, sugar, iron and steel products, salt, and motor vehicles and motor vehicle equipment. The port leads the Nation in the importing of automobiles and ranks second in iron ore concentrates. The majority of these imported bulk commodities are processed by firms in the Baltimore area. Hampton Roads, on the other hand, is an export-oriented port. Well over half (65 percent) of the total freight tonnage passing through Hampton Roads in 1970 was coal and lignite to be exported. Hampton Roads leads the Nation in this category. The port's location in relation to the coal-rich Central Appalachians gives the port a locational advantage over the other East Coast ports in the coal exporting business. Hampton Roads also conducts important trade in the exporting of corn, wheat, soybeans, tobacco leaf, and grain mill products, as well as in the importing of petroleum products, gypsum, lumber and wood products, and chemicals.

Although Baltimore and Hampton Roads contain the only major international deepwater ports in the Estuary Area, there is also a significant amount of traffic in the harbors of some of the smaller ports. These smaller ports include Richmond, Yorktown, Hopewell, Petersburg, and Alexandria, Virginia, along with Piney Point, Annapolis, Salisbury, and Cambridge, Maryland, as well as Washington, D.C. The major commodities shipped through these ports are petroleum and petroleum products, construction materials, fertilizers, and seafood.

Due to the increasing size of oceangoing vessels during the past 100 years and the economies involved in the use of these ships, repeated deepenings and widenings of Chesapeake Bay's ship channels have been necessary in order to keep Bay ports competitive with other ports along the East Coast. In the port of Baltimore, for example, there have been many improvements made by the Federal government, the most notable being the authorized deepenings to 27 feet in 1881, 35 feet in 1905, 37 feet in 1930, 39 feet in 1945, and 42 feet in 1958. More recently Congress has authorized an additional deepening of the main channels to 50 feet. In Hampton Roads there have been numerous improvements of the area's many channels, starting in 1884. The main channel into Hampton Roads was deepened for the first time in 1907 to 30 feet, again in 1910 to 35 feet, in 1917 to 40 feet, and finally in 1965 to

45 feet. The Norfolk District of the Corps of Engineers is currently studying the need for and feasibility of further improving the channels serving Hampton Roads.

In the Chesapeake Bay and tributaries there are a total of 147 authorized navigation projects under the supervision of the Baltimore and Norfolk Districts of the Corps of Engineers. The Maryland Department of Natural Resources has authorized 36 navigation projects in the Chesapeake Bay and tributaries and has completed 16 projects. There are no State projects in Virginia. The locations of the major Federal projects discussed in this appendix are shown on Plates 9-1 through 9-3.

Due to the high sediment loads present throughout most of the Chesapeake Bay system, many of the ship channels are in frequent need of dredging to maintain authorized depths. The frequency of maintenance dredging depends on the location of the waterway. Some waterways, such as the James River, require maintenance almost every year. On the other hand, the Rappahannock Shoal Channel has not been maintained since its deepening to 42 feet in 1964.

Several different types of dredges are used in Chesapeake Bay. The three most common at the present time are the hopper dredge, the cutterhead hydraulic pipeline dredge, and the clamshell dredge. The hopper dredge is a seagoing vessel capable of disposing of material at great distances from the point where it was dredged. Dredging can be performed in depths as shallow as 10 feet and up to 62 feet by the larger vessels. The hopper dredge is used in the Bay Region for dredging the main channel to Baltimore Harbor, the Thimble Shoal Channel at the mouth of the Bay, and Norfolk Harbor.

The cutterhead hydraulic pipeline dredge is adaptable to many types of work and its use is surpassed only on jobs for which special types of dredges have been developed. It is somewhat limited, however, by the fact that it is not self-propelled and that the dredge material must be pumped to a disposal site or vehicle. The clamshell dredge is essentially a derrick on a floating platform. It is an efficient and economical machine for handling earth, soft clay, sand, and mud, where direct deposit on the bank is possible, as in digging drainage canals or building levees from nearby borrow pits.

Two types of dredge material disposal have been used in the past in Chesapeake Bay--open water disposal and disposal in a diked impoundment. In the Upper Bay, open water disposal has been used. Uncontaminated dredge material was generally dumped off the northern shore of Kent Island while contaminated material was disposed of in the Pooles Island area. In the

lower Bay, the Craney Island Disposal Area has been used for all major dredge disposal operations for the Hampton Roads channels. The Craney Island site, constructed in 1957, is a Federally authorized project located in the heart of the Hampton Roads port complex. The defined area, which covers about 2,500 acres and has a capacity of approximately 125 million cubic yards, is projected to be filled to its design height of 17 feet msl by about 1980.

EXISTING PROBLEMS AND CONFLICTS

The major problems and conflicts relative to navigation and waterborne commerce in the Bay Region include:

a. The need for deeper channels to accommodate the larger, modern ships in the world fleet.

b. The maintenance of existing channel depths because of sedimentation and shoaling.

c. The disposal of dredge material from both the maintenance and the deepening of channel projects.

d. Accidental and deliberate discharges of wastes from commercial and recreational craft.

e. Shoreline erosion caused by the wakes from large ships.

f. Conflicts between recreational boating and commercial ships in the major ship channels.

g. Need for additional waterfront lands to accommodate expanding port facilities.

Several of the problems mentioned above stem from a basic confrontation between man's water transportation requirements and the Bay's geological nature. For example, because the Chesapeake Bay is a relatively shallow body of water, major channel deepening projects designed to accommodate today's larger, more efficient ships require extensive dredging. As a result, the channels serving the major ports of Baltimore and Hampton Roads are often not deep enough to efficiently handle the large bulk vessels carrying petroleum, iron ore, and coal in today's world fleet. In addition to the natural shallowness of the Bay, nature's tendency to fill the Estuarine system with sediments and convert it back to a river system causes many existing channels to experience shoaling problems. Dredging and

and dredged material disposal operations are consequently an important and necessary part of commerical navigation activities on Chesapeake Bay and its tributaries. The environmental impacts of these operations has become a very controversial issue in the Chesapeake Bay Region. The principal environmental effects of the actual dredging operation are listed below:

a. Removal by either dredging or filling of the original interface between the water and the bottom, which can be an area of high biological activity;

b. Changes in bottom contours, which may affect current and salinity patterns; and,

c. Increases in turbidity and the possible dispersion of harmful chemicals or organisms into the water.

In most cases, the effects of removal of the existing sediment-water interface are usually localized and of relatively short duration. It should be emphasized that exceptions do occur and that a thorough analysis should be conducted if complications are to be avoided. The circulation patterns of the Bay's waters usually provide opportunities for the re-establishment of available species within 1 or 2 years. One of the few exceptions to this generalization is the oyster, which because of its need for a hard bottom may be more difficult to reestablish. Generally speaking, biological activities will be most drastically altered when soft sediments are removed and replaced by a rock surface (or vice versa). On the other hand, the least damage is likely when dredging or filling merely creates a new face of the same type of sediment. The last situation is the one most likely to be encountered in the Chesapeake Bay Region.

Changes in the bottom contours of an estuary can significantly affect salinity and current patterns. In general, the creation of deepwater areas causes further saltwater intrusion. Saltwater intrusion can cause complex changes in an estuary's ecosystem. These changes may involve both beneficial influences (e.g., improved upstream transport of young crabs, fish, and other species) and detrimental results (e.g., greater upstream penetration of oyster predators and parasites). The net effect will vary with the location and magnitude of the dredging activity as well as the season.

Changes in current patterns can, in turn, cause alterations in salinities, tides, wave action, and numerous other physical and chemical parameters over a much larger area of the Bay than that directly involved in the dredging. Changes in these parameters can also affect biological communities in the impacted area to various degrees.

Turbidity caused by dredging can also create various problems. Suspended sediments can clog and damage the gills of many kinds of animals, reduce photosynthetic activity, and in severe cases, reduce the buoyancy of eggs of marine animals. As the sediments settle, a coating may form on the bottom which interferes with the attachment of young oysters to the beds and which may form soft bottom layers which are uninhabitable for many benthic species. Such sediments, however, frequently occur naturally in estuaries and coastal waters, and many species can tolerate considerable quantities of suspended material. Sediments can also be beneficial to many types of organisms by providing the type of substrate needed by some animals and by carrying nutrients into the marine system. Research in controlling turbidity associated with dredging operations is presently being conducted by the Corps of Engineers Waterways Experiment Station. Results of this program will assess the applicability of silt curtains, chemical flocculants and other improved operational techniques.

Perhaps the most serious environmental problem relating to dredging, and certainly the most emotional, can occur when the dredged material is contaminated by industrial or municipal wastes. Heavy metals, such as mercury, zinc, and lead, along with such substances as pesticides and nutrient salts can have harmful and even toxic effects on aquatic life. There is very limited information on how available such materials become to the marine environment in various chemical forms once they reenter the water. For example, heavy metal contaminants may be tightly bound to the sediment particles physically or chemically or, at the other extreme, simply dissolved in the water mixed with the sediment.

Dr. Kenneth Y. Chen at the University of Southern California is conducting a study entitled the "Effect of Dispersion, Settling, and Resedimentation on Migration of Chemical Constituents During OpenWater Disposal of Dredged Material." This study is part of the Dredged Material Research Program (DMRP) being conducted at the Corps of Engineers Waterways Experiment Station (WES). The preliminary results of this study, presented in an interim report, indicate that concerns regarding the release of a significant quantity of toxic materials into solution during dredging and disposal operations may be unfounded. The tests indicate that while some trace metals may be released in the parts-per-billion range, others show no release pattern, with the exception of iron and manganese. Most of the concentrations of the metals are well below the allowable concentration levels of the 1962 drinking water standards of the U. S. Public Health Service. It was pointed out in the study, however, that trace metals associated with suspended particulates may present some unknown effect

after the disposal of the dredged material. The report concludes by stating that the migration of trace metals from dredge material solution upon disposal in open water is a very complicated phenomenon. The direction and quantity of migration depends on the biochemical variables of the medium (e.g. oxidizing or reducing condition, aerobic or anaerobic). However, due to the low concentrations encountered in most cases, it is doubtful that the input of soluble trace metals from dredging operations will cause any significant environmental effects. Test results on other contaminants such as chlorinated hydrocarbons and nutrients will be included in the final report.

Regarding the most critical areas relative to the problems associated with the disposal of dredge material, the major harbors and approach channels for Baltimore and Hampton Roads and the Chesapeake and Delaware Canal are by far the major problem areas. If for no other reason, the sheer volume of material that must be removed during either periodic maintenance or an overall deepening of these major projects creates disposal problems. When coupled with concerns regarding the quality of the spoils in the urban areas of the harbors, the problem becomes even more critical.

Another source of conflict between waterborne commerce and environmental quality is the deliberate discharge or accidental spilling by vessels of oil, garbage, sewage, and other wastes into the Bay. In 1970, approximately 1.5 million gallons of oil were spilled into the Bay in numerous incidents. The untreated sewage dumped into the Bay by both commercial and pleasure vessels is also a major problem. Unfortunately, these discharges and spills often occur in congested harbor areas with poor flushing action which causes further degradation of often already poor water quality. In addition, environmental quality in the Bay Region is adversely affected by the discharges of pollutants into both the water and air by the industries which are attracted to the area by its water-based transportation system.

Besides its impact on environmental quality, waterborne commerce-related activities can also have significant effects on other aspects and uses of the Chesapeake Bay resource. First, the wave action caused by passing ships is a major cause of erosion in some parts of the Bay. Second, recreational fishing and boating can be disrupted by the wakes from passing ships. In addition, large areas of the Bay and its tidal tributaries are precluded from recreational uses because of their use as anchorages, ship channels, or dredge disposal areas by commercial navigation interests and/or the military. On the other hand, large commercial and military vessels must be constantly on the alert for the smaller recreational vessels to avoid collisions or swampings.

Lastly, the development of a major port is dependent on the concurrent development of land based port-related facilities. However, the development of shoreline land for terminal facilities may in some cases conflict with existing wetlands or proposed recreational use of the same land. Also, port-related facilities because of their locational requirements may be subject to tidal flooding and shoreline erosion.

MANAGEMENT RESPONSIBILITIES

Both Federal and non-Federal entities have certain responsibilities in the planning and construction of navigation projects. The following discussion of Corps of Engineers responsibilities is taken in large part from a publication entitled "Major Steps in Corps of Engineers Water Resource Development," (EP 1105-2-1).

CORPS OF ENGINEERS RESPONSIBILITIES

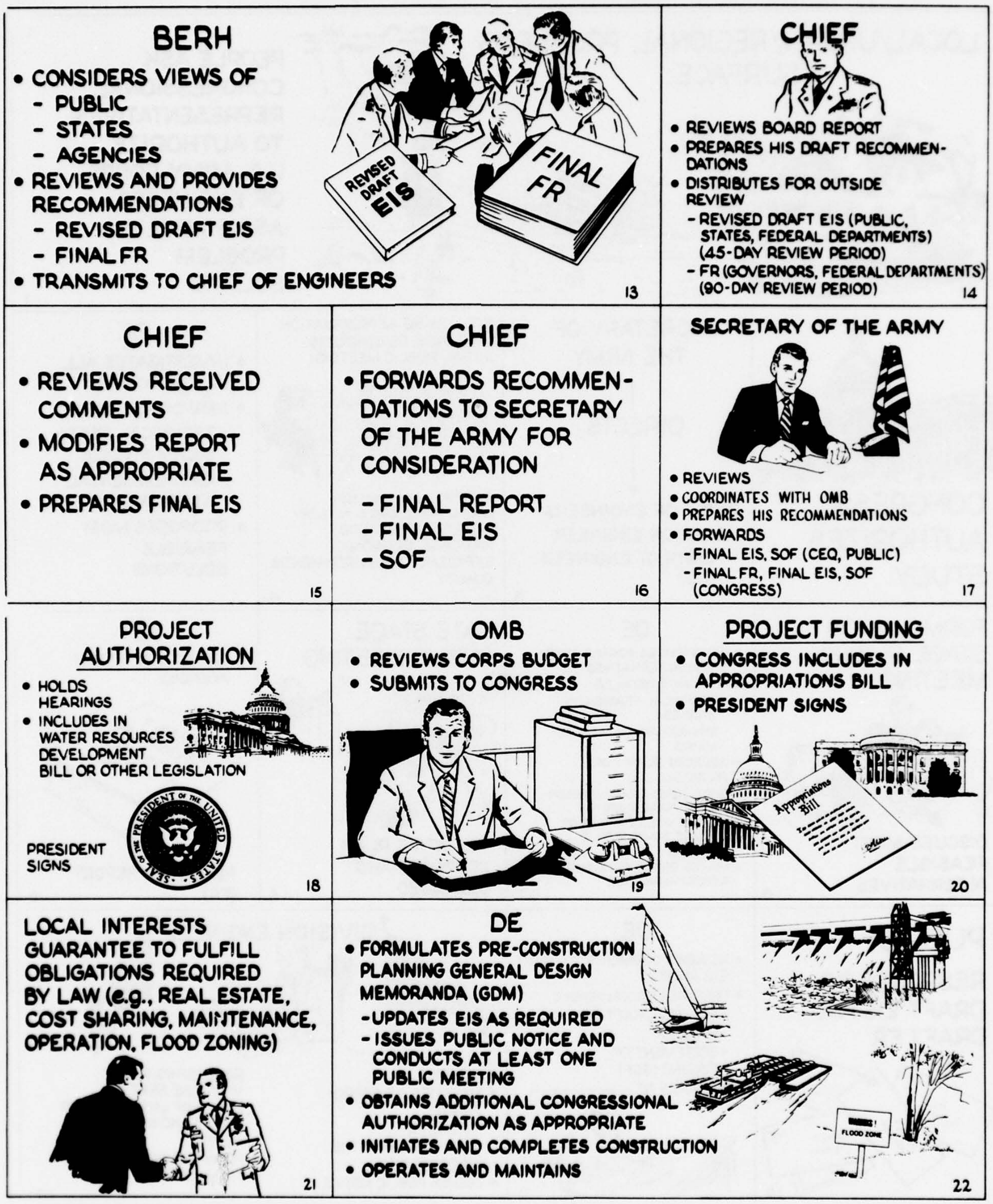
Legal analyses beginning with the Commerce Clause and subsequent Supreme Court decisions have defined that a Federal interest exists in the comprehensive planning of water resources development for long-range needs and in constructing justified projects, with appropriate non-Federal cost sharing, for navigation. All Corps of Engineers navigation projects require specific Congressional authorization, except for certain small projects of limited scope which may be accomplished under general continuing authorities available to the Secretary of the Army and the Chief of Engineers (see the next section). The overall process of conception, authorization, and construction of a project requiring specific Congressional authorization involves 18 major steps which can be grouped into four identifiable phases. These four phases are: a. Study Authorization (Steps 1 to 3); b. Accomplishment of Study (Steps 4 to 6); c. Study Review and Project Authorization (Steps 7 to 12); and d. Advanced Planning, Design, and Construction (Steps 13 to 18). The 18 steps are discussed individually below. Figure 9-2 further illustrates the general procedure.

<u>Step 1. Initiation of Action by Local Interests</u>: Local citizens who desire Federal assistance in improvements for navigation and related water resources purposes contact their U.S. Senators and Representatives and request that provision of the desired facilities be considered by the Federal government. Local interests may also request advice from representatives of the Corps of Engineers on the appropriate procedures,

Figure 9-2: STUDY PHASES

SOURCE: ARMY CORPS OF ENGINEERS, EP 1105-2-10, MAR 75

Figure 9-2: STUDY PHASES



SOURCE: ARMY CORPS OF ENGINEERS, EP 1105-2-10, MAR 75

particularly on whether a study and project may be accomplished under one of the general continuing authorities for small projects.

Step 2. Consultation by Senator or Representatives with Public Works Committee:

a. If previous studies and reports on navigation or related purposes have been made for the area in question, the Senator or Representatives may request the Senate or House Committee on Public Works to adopt a resolution authorizing a review of previous reports to determine whether any modifications of the Chief of Engineers' recommendations in such reports would be advisable.

b. If no previous study and report has been made, the Senator or Representative may request the Committee to include authorization for a study in either a water resources development act or a separate bill.

Step 3. Action by the Senate or House Public Works Committee: Each committee may seek advice from the Chief of Engineers on the desirability of authorizing a particular study. If the committee to which a study request is referred is convinced of the need for the study, it will take appropriate action. In the case of a previous study report, such action is a resolution adopted by the committee, calling upon the Board of Engineers for Rivers and Harbors to make a review and refer it to the Chief of Engineers for action. Where no previous study has been made, the authorization for a study may be included in either a Water Resources Bill or a separate bill for consideration by Congress.

Step 4. Assignment and Funding of Study. When Congress authorizes a study, the Chief of Engineers assigns it to an appropriate reporting officer, usually the Division Engineer in whose region the study area is located. The Division Engineer usually further assigns the study to the appropriate District Engineer. However, before a study can be undertaken, funds for that specific purpose must be appropriated by the Congress and there is generally a time lag of one or more years between study authorization and study funding. Such funding is an entirely separate action.

Step 5. Conduct of Study by Division or District Engineer. The conduct of a study and preparation of a report by a Division or District Engineer is a large undertaking requiring 3 to 5 years, occasionally longer, depending upon the size and complexity of the study. It involves analyses of the engineering, economic, environmental, and social aspects of potential

alternative plans or solutions. Coordination with interested Federal and non-Federal agencies and other groups and individuals is an integral part of the study process. Public involvement is encouraged, and public meetings are held as one means of fostering such involvement. The development and review of draft environmental impact statement is also a part of this overall process.

Basically, a study seeks to identify and assess the water and related resources problems and needs in the area under study; define and analyze potential alternative solutions, their effects, and feasibility; and select the most feasible plan, or solution, if there is one. This includes evaluating the various economic, environmental, and social effects and estimating the tangible benefits, costs, and cost sharing. A favorable recommendation depends upon a project's overall effects, including tangible benefits and costs, and upon obtaining from responsible non-Federal officials a written expression of their intent to participate in the project. In the case of a navigation project, non-Federal interests must agree to:

(1) Contribute in cash the local share of project construction costs, determined in accordance with existing policies for regularly authorized projects. Local interests are required to perform or contribute one-half the first cost of construction of the project allocated to such local benefits as recreation and land enhancement. In addition, recent executive policy requires local interests to perform or bear the cost of project operation and maintenance (O & M) allocable to recreation. Navigation benefits accruing to commercial interests are considered general and widespread. For such improvements, construction and O & M are provided at Federal cost. In addition, the Water Resources Development Act of 1974 provides that the cost of operation and maintenance of general navigation features of smallboat harbors (recreation boating) shall be borne by the Federal government.

(2) Provide, maintain, and operate without cost to the United States all necessary lands, easements, and rights-of-way required for construction and subsequent maintenance of the project including suitable spoil disposal areas with any necessary retaining dikes, bulkheads, and embankments therefor.

(3) Hold and save the United States free from damages that may result from construction and maintenance of the project.

(4) Accomplish without cost to the United States alterations and relocations as required in sewer, water supply, drainage, and other utility facilities.

(5) Provide and maintain berthing areas, floats, piers, slips, and similar marina and mooring facilities as needed for transient and local vessels, as well as necessary access roads, parking areas, and other needed public-use shore facilities open and available to all on equal terms. Only minimum basic facilities and services are required as part of the project. The actual scope or extent of facilities and services provided over and above the required minimum is a matter for local decision. The manner of financing such facilities and services is also a local determination.

(6) Perform, or contribute the cost of performance of, that part of the operation and maintenance of the project allocable to recreation.

Typically, a study begins with a preliminary study to determine if there is sufficient reason to spend time and money on a detailed study. Coordination and public involvement begin early in this stage. This includes an initial public meeting to discuss the study and seek the views and desires of local people. Such meetings are publicized and copies of an announcement are sent directly to all those known to be interested. If the preliminary study indicates that a feasible plan is possible, a more detailed study is made. At this time a formulation-stage public meeting is held, during which the study results thus far are presented. As the study nears completion and the most feasible plan becomes more apparent, general coordination is continued, the draft environmental impact statement is developed and coordinated, a late-stage public meeting is held, and the final report is prepared.

Step 6. Issuance of Report and Public Notice by Division Engineer. Upon completion of the report of the District Engineer, the Division Engineer having jurisdiction reviews the report and transmits it with his recommendations and accompanying papers to the Board of Engineers for Rivers and Harbors. For a study and report accomplished by a Division Engineer instead of a District Engineer, the completed report is similarly transmitted to the Board. At this time, the Division Engineer also issues a public notice to all persons known to be interested, setting forth the findings of the study and the report recommendations, and inviting those who wish to do so furnish further views to the Board. It is at this time that the field report is considered complete and official, and may be purchased at the cost of reproduction.

Step 7. Review by the Board of Engineers for Rivers and Harbors. The Board of Engineers for Rivers and Harbors, an independent review group with a staff in Washngton, D.C., is required by law to review all Corps of Engineers study reports

specifically authorized by Congress, except for those which are under the jurisdiction of the Mississippi River Commission. The Board may hold public meetings before making its recommendations to the Chief of Engineers. A reviewed report is transmitted, with recommendations to the Chief of Engineers.

Step 8. Preparation and Coordination of Proposed Report of the Chief of Engineers. Following receipt of a report and recommendations from the Board, the Chief of Engineers prepares his draft report and forwards copies of the report with accompanying papers to the Governors of the affected States and to other interested Federal agencies for formal review and comment. The revised draft environmental impact statement is also circulated for comment at this time. The Federal agencies generally involved may include, but are not limited to, the Departments of Agriculture, Transportation, Commerce, Interior, and Health, Education and Welfare, the Federal Power Commission, and the Environmental Protection Agency. The states and Federal agencies are normally expected to forward their comments to the Chief of Engineers within 90 days.

Step 9. Transmittal of Report to the Secretary of the Army. After the Chief of Engineers receives and considers the comments of the Governors of the affected States and those of other interested Federal agencies, as well as all comments on the revised draft environmental impact statement, he prepares his final report and the final environmental impact statement. The Environmental Protection Agency is the only agency whose opposition to a project cannot be overruled by the Secretary of the Army. In general, however, if the Governor of one of the affected States is opposed, the project is dropped or another alternative is chosen. The Chief of Engineers then submits the report along with the environmental impact statement and other pertinent papers to the Secretary of the Army.

Step 10. Referral of the Report to the Office of Management and Budget. The Secretary of the Army submits a draft of his letter of transmission to Congress, along with the report of the Chief of Engineers and all pertinent papers, to the Director of the Office of Management and Budget for a determination of the relationship of the report to the program of the President.

Step 11. Transmittal of Report to Congress. Upon receipt and consideration of the comments of the Office of Management and Budget, the Secretary of the Army transmits the report of the Chief of Engineers, with all pertinent papers and comments, to the Congress. This step completes the action required of the Chief of Engineers and the Secretary of the Army in complying with the Congressional resolution or act authorizing the

study. The final environmental impact statement is also filed with the Council on Environmental Quality at this time and is available to the public.

Step 12. Project Authorization by Congress. After the report is forwarded to Congress by the Secretary of the Army, it is printed as a Senate or House document, which is referred to as the project document. The Committees on Public Works of the Senate and the House may hold hearings on the report and consider those projects recommended in the report for inclusion in an authorization bill. Authorization for construction of projects is usually included in the Water Resources Development Act. Project authorization may also be by resolution by both Public Works Committees rather than by an act when such a project has a Federal cost of less than $10 million. In all cases, however, Congress must appropriate funds before advanced planning, design, and construction can be undertaken. Funding of these activities is an entirely separate action.

Step 13. Project Scheduling and Reaffirmation of Local Cooperation. Since budgets are limited, authorized projects are in competition with each other for funding. When a District Engineer is considering the scheduling of advanced planning, design, and construction of an authorized project, a pertinent factor is the availability of the required local cooperation. When appropriate, the District Engineer notifies responsible non-Federal officials concerning the required local cooperation. If satisfactory assurances are not received regarding intent to furnish local cooperation, the project is considered inactive.

Step 14. Request for Project Funds. In order to undertake a project authorized by Congress, funds for advanced planning, design, and construction must be requested from Congress. All requests for such funds are made annually through the Office of Management and Budget. If found to conform with the President's budgetary policies, the requests are transmitted to the Congress as part of the President's budget and later considered by the Appropriations Committees.

Step 15. Appropriation of Project Funds. After completion of hearings by the Appropriations Committees considering the Department of the Army Civil Works Appropriations, a bill is reported out of committee and referred to the full Congress for passage. The enactment then goes to the President for signature. Authority and funds are thereby given to the Chief of Engineers to initiate advanced planning, design, and construction of the projects included in the act. Generally, further appropriations are required in succeeding years until the project is completed.

Step 16. Preparation of Detailed Plans. Before construction of a project can start, advanced planning and detailed design must be accomplished by the District Engineer, with such assistance, review, and approval by the Division Engineer and the Chief of Engineers as are necessary. The preparation of detailed plans averages several years, depending upon the type and size of project. Essentially, this process begins with a review and updating of the basic plan authorized and proceeds through progressively more detailed design to produce construction plans and specifications along with detailed cost estimates. A public meeting is also held in connection with the advanced planning. If the changes in the basic plan authorized are substantial, a draft environmental impact statement is subsequently filed. Coordination with the affected States, other Federal agencies, and other affected interests is also maintained during advanced planning and design. At this time, the formal agreements and local cooperation required by law, of which local interests were notified in Step 13, must be provided by local interests and approved by the Secretary of the Army.

Step 17. Award of Contract. Upon completion of detailed construction plans and specifications for a project or a separable portion of it, qualified contractors are invited to bid on the construction of the proposed improvements. A contract is then awarded to the eligible low bidder for construction in accordance with the plans and specifications.

Step 18. Construction of Project. After award of a contract, the successful bidder mobilizes his equipment and personnel and starts construction. The work is accomplished under the technical direction of Corps of Engineers personnel to insure that it conforms to the contract requirements. Upon completion of a project, which may involve more than one contract, a final sharing of the cost is determined and the Corps of Engineers or local interests assume operation and maintenance of the project in accordance with authorized requirements. Construction averages 3 to 4 years but may take more or less time, depending upon the type and size of project.

As mentioned earlier, small navigation projects may also be constructed under continuing authorities which permit the Corps of Engineers to undertake investigations and construction of projects having a Federal cost not exceeding $2,000,000. A project under this type of authority is the same independent and complete-within-itself project that would be recommended under the regular authorization procedures discussed in the preceding paragraphs.

The nine major steps for small navigation projects under continuing authorities are summarized below.

Step 1. Initiation of Action by Local Interests. Local citizens who desire Federal assistance in small localized improvements for navigation that qualify under continuing authorities should have their local officials contact the appropriate District Engineer and request that the desired improvements be considered by the Federal government.

Step 2. Determination by the District Engineer. The District Engineer investigates the problem or need. He determines if there is an appropriate Federal interest and if a study is in order and within the authorities available. If appropriate, he initiates a preliminary study, which may lead to approval of a detailed study.

Step 3. Conduct of Study by District Engineer. The conduct of studies and preparation of reports by a District Engineer averages several years for a typical navigation project. The study concept and process are essentially the same as presented in Step 5 for projects requiring specific Congressional authorization. The main difference for a small project under continuing authority is that if a preliminary study reveals sufficient reason to proceed with a detailed study, authority and funds to accomplish the detailed study are sought from the Chief of Engineers through the Division Engineer. Another difference is that normally only one public meeting is held, although normal coordination, including circulation of a draft environmental impact statement, is accomplished.

A different distinction can be made for specific improvements under still smaller authorities of limited purpose and cost, such as for the snagging and clearing of channels. These improvements normally involve only a simple study and letter report. Also, a public meeting is not normally held, although normal coordination, including circulation of a draft environmental impact statement, is accomplished in this case also.

Step 4. Issuance of Report by Division Engineer. Upon completion of the detailed report or letter report of the District Engineer, the Division Engineer having jurisdiction reviews the report and transmits it with his comments and accompanying papers to the Chief of Engineers. This step is similar to Step 6 for a project requiring specific Congressional authorization.

Step 5. Review and Approval by the Chief of Engineers. The Chief of Engineers reviews the detailed or letter report and files the final environmental impact statement with the Council on Environmental Quality. Approval by the Chief of Engineers constitutes project authorization.

Step 6. Request for Project Funds. In order to undertake the advanced planning, design, and construction of an approved project, funds must be requested from the Chief of Engineers. Funds for the small project programs are budgeted annually, and normally sufficient funds are available when needed. However, there may be occasions when funding is delayed pending further appropriations for these programs.

Step 7. Preparation of Detailed Plans. Before construction of a project can start, advanced planning and detailed design must be accomplished by the District Engineer, with such reviews and approval by the Division Engineer as necessary. The end result is construction plans and specifications along with detailed cost estimates. Coordination with affected agencies and other interests is maintained during this period. At this time, the formal agreements and local cooperation required must be provided. These projects are subject to the same local cooperation requirements as those projects specifically approved by Congress except for the additional requirement that the non-Federal interests must agree to assume full responsibility for all project costs in excess of the Federal cost limitation of $1 million.

Step 8. Award of Contract. Upon completion of detailed construction plans and specifications, qualified contractors are invited to bid on the construction of the proposed improvements. A contract is then awarded to the eligible low bidder for construction in accordance with the plans and specifications.

Step 9. Construction of Project. After award of the contract, the successful bidder mobilizes his equipment and personnel and starts construction. The work is accomplished under the technical direction of Corps of Engineers personnel to insure that it conforms to the contract requirements. After completion of a project, a final sharing of the cost is determined, and the Corps of Engineers or local interests assume operation and maintenance of the project in accordance with the local cooperation requirements.

STATE RESPONSIBILITIES FOR CONSTRUCTION OF PROJECTS

a. Background. The State of Maryland's program for constructing navigation projects was started in fiscal year 1969 and is carried out by the Dredging Section under the Assistant Secretary for Capital Programs, Maryland Department of Natural Resources (DNR). Projects constructed under the program are authorized under Article 14B of the Maryland Boat Acts of 1960 and paid for by the Waterway Improvement Fund which receives funding from boat registration and titling fees.

Under Maryland law, a governing body is authorized to establish and designate geographical areas within its jurisdiction as waterways improvement districts and refer them to DNR. DNR then reviews the proposed district and submits a report to the governing body containing recommendations on the feasibility and need for the proposed district. The report designates areas to be included within the district, work or projects to be carried out, and the estimated costs for the work or projects recommended.

With the exception of funds for boating safety and education, all funds in the Waterways Improvement Fund are used solely for the following projects: (1) Marking of channels and harbors not within the scope of operations of the U.S. Coast Guard; (2) Clearing of debris, aquatic vegetation, and obstructions from navigable waters of the State; (3) Dredging of channels and harbors not within the scope of operations of the U.S. Army Corps of Engineers; and (4) Construction of marine facilities beneficial to the boating public.

Projects for the marking and dredging of channels and the clearing of debris are paid solely by the Waterways Improvement Fund. Projects for the construction of marine facilities are financed jointly by the governing body and the Waterways Improvement Fund with the Fund paying no more than 50 percent. It may be financed solely by the Fund if the total cost is less than $25,000.

b. Procedure. The following is a description of the general procedure by which navigation projects are constructed by the State of Maryland.

(1) The local governing body makes a request to DNR describing the project which should include preliminary drawings or sketches showing the desired project, dredge material disposal areas, property owners, public facilities, a description of the project, and the benefits to be derived by the boating public.

(2) DNR then makes a reconnaissance-type study to determine if the project is practical and feasible and informs the local citizens of the results.

(3) If the project is feasible, the local governing body must then: (a) Provide to the State of Maryland without cost all easements and rights-of-way required for construction and maintenance of the project including spoil disposal areas (b) Submit a statement holding the State free from damages that may result from construction of the project; and (c) Submit an agreement to accomplish without costs to the State, alterations

and relocations as required in sewer, water supply, drainage, and other utility facilities.

(4) After the above requirements have been submitted and reviewed by DNR, they are then submitted to the Commission on Chesapeake Bay Affairs, which will review the project. If the project is approved, it will be included in DNR's budget request.

(5) The State or the local governing body must then apply for a permit from the U.S. Army Corps of Engineers giving a description of the work to be done and the location of the spoil disposal area.

(6) When the project is approved, the applicant will proceed with the following: (a) Develop detailed plans and specifications for the project and submit to DNR for approval or comment; (b) Obtain all necessary permits; and (c) Advertise and solicit bids. The governing body prepares a tabulation of bids and submits it to DNR with comments and recommendations prior to the award of the contract.

(7) After award of the contract, the successful bidder will mobilize his plant, equipment, and personnel, and start construction.

The Commonwealth of Virginia does not have a program for constructing navigation projects.

OTHER FEDERAL AND STATE RESPONSIBILITIES

Corps of Engineers - Specific, limited programs for continuing debris collection and disposal are authorized by Congress on an industrial basis and the work is carried out by the Corps at each locality as a separate, distinct project. Within the Chesapeake Bay and tributaries debris collection projects have been authorized in Baltimore and Norfolk Harbors and in the Potomac and Anacostia Rivers in Washington, D.C.

United States Coast Guard - Enforces or assists in the enforcement of all applicable Federal laws on navigable waters, including water pollution abatement. In addition to the abatement of "hazardous substances," the ultimate responsibility for oil spills is the Coast Guard's. If a spiller is unknown, the Coast Guard cleans up the spill and starts an investigation to find the spiller. Also, the Coast Guard contains oil spills by placing booms around the spill.

It should be noted that the Coast Guard has developed the Chemical Hazards Response Information System (CHRIS) which

is designed to provide timely information essential for proper decision making by responsible Coast Guard personnel and others during emergencies involving the water transport of hazardous chemicals. A secondary purpose is the provision of certain basic non-emergency related information to support the Coast Guard in its efforts to achieve improved levels of safety in the bulk shipment of hazardous chemicals.

The Coast Guard also administers laws and enforces regulations for the promotion of safety of life and property in matters not specifically delegated to another executive department or reserved to the states, establishes anchorage areas, and administers and enforces Merchant Vessel Inspection Regulations. In addition, the Coast Guard develops, establishes, maintains, and operates aids to navigation and rescue facilities for the promotion of safety on the waters of the Bay.

Environmental Protection Agency - Ultimate authority for overboard dumping of domestic wastes stem from Section 312 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). This section, as amended on 2 January 1975, requires that all new ships meet "zero discharge" requirements by 30 January 1977 and that existing ships comply by 30 January 1980. Guidelines have been set up by the Environmental Protection Agency (EPA) and official standards and enforcement are the responsibility of the United States Coast Guard in their areas of jurisdiction. "Zero discharge" in this case has been defined as no overboard disposal of raw wastes and will essentially require the suitable flow-through devices as determined by EPA and USCG.

Should an individual state feel the need for more stringent standards, they may apply to EPA in two ways for approval of their intended standards. By applying under authority of Section 312(f)3, state standards will be adopted for that area by EPA and the USCG will remain the enforcement agency. If, however, the states apply through Section 312(f)4, the EPA will require that adequate marina facilities are installed by the applying state's Department of Health and that enforcement of these standards be accomplished by the appropriate state agency.

In the case of the Commonwealth of Virginia, application through Section 312(f)4 of P.L. 92-500 has been initiated as of 27 March 1976. Known as "Regulation 5", this action seeks approval from EPA for immediate enforcement of "zero discharge" by the Virginia State Water Control Board (VSWCB) in all known shellfish areas. Approval from EPA has been delayed, primarily because of the very few existing pumping and disposal facilities in established marinas. However, less stringent and

more workable requirements for marina facilities have recently been adopted by the Virginia State Department of Health and many marinas are beginning to install facilities. Approval by EPA is therefore expected in the near future and enforcement programs are currently being prepared by the VSWCB.

Maryland Port Administration - Endeavors to promote and increase commerce within its territorial jurisdiction through publications, public relation programs, purchase of advertising, solicitation of business by correspondence and traveling representatives, and participation in, and cooperation with, civic, technical, professional, and business organizations and associations. (8) In pursuit of its mission, the promotion and increase of commerce at the Port of Baltimore, the Administration is responsible for the planning, development, and improvement of the Port's facilities and support of the efforts of the private operator. If private facilities are inadequate, the Administration is empowered to construct and operate supplementary public facilities.

Maryland Marine Police - Responsible for the enforcement of laws and regulations pertaining to fish, crabs, oysters, clams, terrapins, fish kills, trash dumping, littering, or oil spills in Maryland's portion of Chesapeake Bay. (9)

Maryland Department of Natural Resources

a. Natural Resource Police Force - Responsible for the enforcement of fish, boating, wildlife, conservation, and other natural resources laws. The organization also gives assistance to the hunting and boating public. (10)

b. Fisheries Administration - Responsible for the supervision of commercial seafood harvest and licensing of commercial watermen; investigation of fish mortalities; research of shellfish disease; planting of oyster shells and transplanting of seed oysters. (11)

c. Maryland Geologic Survey - Responsible for the publication of maps, survey of archeological sites, and the examination of offshore depth changes. (12)

d. Water Resources Administration - Responsible for the monitoring of dredging and dredge material disposal operations in the State of Maryland.

Virginia Port Authority - Generally, has the responsibility to perform any function which may be useful toward the improvement of the harbors and seaports themselves, or the commerce through the ports.

More specifically, the Port Authority is responsible for:

1) seeking to consolidate the water terminals of the cities within the ports (general cargo terminals have been consolidated);

2) promoting a spirit of cooperation among these cities in the interest of the ports as a whole;

3) initiating and furthering plans for the development of the ports, keeping informed as to present and future needs; and

4) seeking to secure the improvement of navigable tidal waters, where such improvements are economically justifiable. (13)

Pilot's Association, Virginia and Maryland - Responsible for providing pilots for ships originating in foreign ports, and to guide the ships into the ports of the respective states. In addition to providing pilots for foreign ships, the Virginia Pilots Association provides pilots for Navy ships bound for Washington, D.C.

Hampton Roads Sanitation District Commission - Responsible for providing abatement of pollution in the Hampton Roads, lower Chesapeake Bay, and nearby tributaries. (14)

Marine Resources Commission - Responsible for administering, and enforcing Sections of the Code of Virginia and for making necessary regulations to promote the welfare of the seafood industry and to conserve and promote the seafood and marine resources of Virginia. (15)

Virginia Institute of Marine Science - Conducts monitoring of dredging and dredge material disposal operations in Virginia.

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CHAPTER III

FUTURE WATERBORNE COMMERCE NEEDS

This chapter presents the findings of the future supply/demand projections phase of the Chesapeake Bay Study as related to waterborne commerce. It identifies and discusses future waterborne commerce related demands, supplies, needs, and problems.

FUTURE DEMANDS

ASSUMPTIONS

The projections of waterborne commerce in this appendix are based on the Series C OBERS projections of population and economic activity prepared by the Bureau of Economic Analysis, BEA, formerly the Office of Business Economics, OBE, U. S. Department of Commerce, and the Economic Research Service, ERS, U. S. Department of Agriculture with assistance from the Forest Service. These projections were prepared for the following geographical areas:

a. The total United States;

b. The 50 individual States and the District of Columbia;

c. The 20 water resources regions and the 205 subareas delineated by the Water Resources Council (WRC) in the publication Water Resources Regions and Subregions for the National Assessment of Water and Related Land Resources, July 1970;

d. The 173 economic areas delineated by BEA for economic analysis;

e. A special breakdown prepared by BEA of the economic areas within the Chesapeake Bay Region to the SMSA and non-SMSA level by State. This special breakdown was originally presented in the Chesapeake Bay Existing Conditions Report: Appendix A - "The People and the Economy" and is included in Appendix 3 of this report.

The OBERS projections are based on long-run trends and ignore the cyclical fluctuations which characterize the short-run path of the economy. The general assumptions that underlie the Series C projections at the National level are listed below:(16)

a. Growth of population will be conditioned by a gradual decline of fertility rates from the level prevailing in the mid-1960's to 2,777 children per 1,000 women (over their lifetimes) in the year 2000.

b. Nationally, reasonably full employment, represented by a 4 percent unemployment rate, will prevail at the points for which projections are made; as in the past, unemployment will be disproportionately distributed regionally, but it is assumed that the extent of disproportionality will diminish.

c. No foreign conflicts are assumed to occur at the projection dates. The United States military force based in this country is assumed to remain constant at 2.07 million persons.

d. Continued technological progress and capital accumulation will support a growth in private output per man-hour of 3 percent annually.

e. Hours worked per year per man in the private economy is assumed to decline at a rate of 0.25 per year.

f. The new products that will appear will be accommodated within the existing industrial classification system, and, therefore, no new industrial classifications are necessary.

g. Growth in output can be achieved without ecological disaster or serious deterioration, although diversion of resource for pollution control will cause changes in the industrial mix of output.

h. Employment/population ratios will vary between 0.40 and 0.41.

The projections prepared for geographical areas below the National level are based on the following additional assumptions:

a. Most factors that have influenced historical shifts in regional "export" industry location will continue into the future with varying degrees of intensity. Regional breakdowns of National projections are based on extensions of historical trends in the relationships between industrial growth in the region and industrial growth in the United States as a whole.

b. Trends toward economic area self-sufficiency in local service industries will continue.

c. Workers will migrate to areas of economic opportunities and away from slow-growth or declining areas.

d. Regional earnings per worker and income per capita will continue to converge toward the National average.

e. Regional employment/population ratios will tend to move toward the National ratio.

Regional assumptions "d" and "e" are corollaries of assumption "c." In some circumstances they may be counterbalanced by other forces. The migration of retired people to attractive retirement areas *without regard to economic opportunity* is an example of this counter-effort.

Due to the lack of an adequate historical base, the OBERS projections do not reflect the current energy problems, recent changes in agricultural exports, and recent changes in conservation and environmental activities.

Critical to the understanding of the OBERS projections, and therefore, the projections of waterborne commerce in this appendix, is the level of water resource development implied in the OBERS projections. The OBERS projections are a function of past economic and demographic trends which have been influenced to some extent by water resource development and to this extent continued water resource development is implied in the projections. Water resource planning as conducted today requires an analysis of the difference between a future economy and environment which includes the effects of resources development (the "with" condition) and one which excludes the effects of such development (the "without" condition). One approach to a determination of the "with" or "without" character of the OBERS projections for any area

involves, first, a determination of the supply of water and related land resources that will be available at future dates with existing or pre-specified levels of development; second, an estimation of the demand for water resources required to sustain the level and composition of economic activity and population projected by OBERS; and third, a comparison of the projected supplies and demands. When the projected supplies of water resources are insufficient to satisfy the projected level of water use, the OBERS projections are referred to as the "with" condition. If the OBERS projected levels of economic activity are determined to be desirable, the possibilities for water resource development should be investigated. When the future supply of water and related land resources is expected to be greater than or equal to projected demands, the OBERS projections are referred to as reflecting the "without" condition. Two options may be considered in the latter case. First, further water resource development may be deemed to be unnecessary. Second, even though the initial analysis shows that the expected water resource development is adequate to sustain the baseline projections, consideration may be given to further development as a means of accelerating regional economic development. (17)

There are several additional assumptions which were made for the actual projections of waterborne commerce. These will be discussed in the following section.

METHODOLOGY

GENERAL

In preparing the projections of future levels of waterborne commerce on the major waterways of Chesapeake Bay, three basic sources of data were used. The first source was the OBERS historical and projected values for population, income, earnings, and manufacturing output as described in the preceding section. The second source was the Army Corps of Engineers' publications, Waterborne Commerce of the United States for the years 1953 through 1972. These reports present detailed data on the movements of commodities and vessels at the ports and harbors and on the waterways and canals of the United States, the Commonwealth of Puerto Rico, and the Virgin Islands. Both foreign and domestic waterborne commerce is included. The last source was unpublished Corps of Engineers' data concerning port of origin and destination by commodity for Chesapeake Bay area domestic shipments.

In addition to the above sources, reports from other studies which had investigated future levels of commerce for Chesapeake Bay area ports and waterways were consulted. The U.S. Deepwater Port Study, "Commodity Studies and Projections", prepared by Robert R. Nathan Associates, was especially useful in the projection of exports of bulk coal, bulk grains, and import iron ore. In all cases, historical data was updated and any related recent developments were assessed as a test of the continuing validity of the projections prepared by Nathan.

The first step in the projection methodology was to aggregate into six commodity groupings the commodity data from the Waterborne Commerce publications for the years 1953-1972. The groups and the types of commodities included in each are listed below.

a. Bulk Oil

(1) Crude Petroleum
(2) Gasoline
(3) Jet Fuel
(4) Kerosene
(5) Distillate Fuel Oil
(6) Residual Fuel Oil
(7) Miscellaneous Petroleum Products

b. Bulk Coal (Coal and Lignite)

c. Bulk Ore (Metallic Ores)

d. Bulk Grain

(1) Corn
(2) Wheat
(3) Soybeans and Soybean Meal
(4) Miscellaneous Grains

e. Miscellaneous Bulk

(1) Limestone
(2) Sand, Gravel, and Crushed Rock
(3) Phosphate Rock
(4) Salt
(5) Sulfur
(6) Gypsum
(7) Other nonmetallic minerals
(8) Sugar
(9) Molasses
(10) Sodium Hydroxide
(11) Sulfuric Acid
(12) Fertilizers
(13) Coke
(14) Liquefied Gases

f. General Cargo (All Other Commodities)

There were two criteria used in developing these commodity groups. First, the groups should be relatively homogenous as to the type of vessel in which the commodities are shipped. For

example, commodities in the bulk oil group are generally transported long distances by tankers, while bulk ores and bulk coal are usually shipped in dry bulk carriers.

The second criteria was that the demand (level of traffic) for the various commodities within a group would be sensitive to similar economic and demographic variables.

Because of the differences in relative importance to the Chesapeake Bay Region and Nation of the various harbors and waterways included in this analysis projections were made to varying degrees of detail. Baltimore and Hampton Roads, due to their roles as ports of international importance, were analyzed in depth on a commodity group and in many cases a single commodity basis. On the other hand, projections for several of the relatively smaller ports (in terms of tonnage) were made for two groups only--bulk oil and the total of all other commodity groups. Activities in other ports and waterways were projected to appropriate levels of detail between these two extremes.

After the historical waterborne commerce data were collected to the appropriate detail for a given port, the second step in the analysis was to determine the shipped commodity or group of commodities. In the case of domestic or foreign imported raw materials or partially finished goods, processing is usually done by factories in the vicinity of the port and then distribution is made to various sized geographical areas depending on the type of product and the market area controlled by the factories. Whether they are processed or not (e.g., petroleum products), a "distribution area" was delineated for each projected commodity or group of commodities. Statistical relationships were then established, whenever possible, between historical levels of commerce and past levels of population, income, earnings, and/or manufacturing output in the "distribution area." For example, gypsum is imported into Baltimore by several firms where it is processed into plasterboard and other related construction materials. These finished materials are then distributed to various points in the Middle Atlantic region. A good statistical relationship exists between historical movements of gypsum into Baltimore and population growth in the Middle Atlantic states. By extending this historical relationship between population and the level of traffic forward to the year 2020, estimates can be made of future gypsum movements into Baltimore by using the OBERS population projections for the Middle Atlantic states.

The major statistical tools used in this analysis are simple and multiple regression analyses, the coefficient of determination (R^2), and the student t-value. The critical student t-value is

calculated at 95 percent level of confidence throughout this report. When no statistically significant relationship can be found between historical movements and past economic, demographic, and/or temporal values at the 95 percent level, movements are assumed to remain at a constant level in the future unless information to the contrary is available. Total income for a given area was often used in the models as a proxy for total economic activity in an area since it includes the effect of changes in both population and per capita income.

Except where specifically noted in the text, existing trade routes for given commodities and existing harbor sites are assumed to remain unchanged in the future. Table A-1 in Attachment A shows the destination by both harbor and commodity of the waterborne commerce entering the Bay.

In some commodity groups, bulk oil being the most notable example, modifications were made to the general methodology discussed above. The following sections summarize these modifications by commodity category.

BULK OIL

The demand for petroleum and petroleum products in the United States has increased dramatically during the last several decades, averaging about 3.5 percent per year since 1960. At this rate, the United States alone will use all of the world's proven petroleum reserves (as of 1970) by the year 2015. Although proved reserves can be increased substantially in the future--the National Petroleum Council estimates that proved reserves could be doubled in the next 15 years (18)--it is generally accepted that these rates of growth cannot continue for too much longer. The question that arises is: How should projections of demand for petroleum products based on historical trends be adjusted to account for an expected "dampening" of the increase in demand for these products in the future? Before this question can be answered, however, an even more basic problem must be addressed: Are significant savings in energy use in the United States possible?

First, looking at the total energy picture, it is the general consensus of opinion of experts in the energy field that significant savings can be made in total energy use by industrial, commercial, and domestic users. For example, a recent study published by the Ford Foundation's Energy Policy Project entitled "Potential Fuel Effectiveness in Industry," estimated that major industries could operate on one-third less energy if existing technology were fully applied. The study concentrated on six industries which together accounted for 15 percent

of the Nation's total energy use. Former Department of Commerce Secretary Frederick Dent, reporting on a series of studies conducted by the Commerce Department on the theoretical minimum energy requirements in nine major industries, stated that his agency believes that energy savings of about 15 to 20 percent are possible in the industrial sector over the next several years.(19) There are also many opportunities for energy conservation in non-industrial uses. Since transportation accounts for about 25 percent of our total energy consumption, significant energy savings are possible through increased car pooling, wider use of public transportation, lower highway speed limits, fewer airline flights on the less frequently used routes, and a shift toward smaller cars. Less frequent and/or intensive use of air conditioners and heaters in homes and commercial establishments is another possible method of energy conservation.

The major inducement for these energy conservation measures will probably be increases in the prices of the various energy sources. A study by William D. Nordhaus entitled "The Allocation of Energy Resource" projects the prices of electricity, coal, natural gas, and petroleum products to the year 2010. In this report, electricity prices are estimated to increase at a very moderate rate (about 1.1 percent annually) over the next forty years as full adaptation to a nuclear technology takes place. The calculated price of coal rises at an even slower rate of about 0.7 percent annually over the same period. Estimated price increases for petroleum and petroleum products, as well as natural gas, rise at a much faster rate. Petroleum increases at between 4.6 and 3.5 percent annually (depending on the type of product), while natural gas is expected to increase at about 3.9 percent annually (20). Considering the fact that the demand for these energy sources have negative price elasticities, that is, increases in prices mean decreases in demands, the findings of the Nordhaus study tend to support the belief that there will be a dampening of the increase in demand for energy, and especially for petroleum and petroleum products. (The demand for energy is also a function of many other variables such as per capita income and population which have positive elasticities. Future increases in income and population will most probably partially compensate for the negative effects of price increases so that there will continue to be a general increase in the demand for energy but a slowing in the rate of increase.) This view was also supported by a study by the U. S. Department of Interior entitled "United States Energy: A Summary Review." This study predicted that the proportion of the total U.S. energy requirements met by petroleum and petroleum products would decrease from 43.0 percent in 1970 to 34.6 percent in the year 2000.(21)

Having established the principle that some dampening of the increase in demand for petroleum and petroleum products is not only possible but probable, we can now address our first question: What modification should be made to the projections of the demand for petroleum products based on historical trends to take this dampening into account?

In this Appendix, the following adjustments were made to the growth rates of the "unrestrained" (i.e., unadjusted extention of historical trends) projections.

Decade	Adjustments to Growth Rates of the "Unrestrained" Projections
1970 - 1980	80% of unrestrained growth rate
1980 - 1990	60% of unrestrained growth rate
1990 - 2000	40% of unrestrained growth rate
2000 - 2010	30% of unrestrained growth rate
2010 - 2020	20% of unrestrained growth rate

These percentages are admittedly arbitrary, but the methodology has at least two major advantages over a straight line extension of historical trends. First, the adjusted projections do take into account the expected dampening of the increase in demand for petroleum products discussed earlier. Second, they reflect the belief that this dampening is not a temporary phenomenon but will, in fact, increase in intensity over time. Based on the information presented above on the potential for energy conservation, it is believed that this adjustment methodology is not unreasonable, and is, in fact, probably conservative.

Figure 9-3, showing the waterborne receipts of bulk oil into Baltimore and Hampton Roads (bulk oil is essentially an import item in Chesapeake Bay), does not reflect the significant increases in the demand for petroleum products which, in fact, have occurred in these areas. Starting in the early 1960's, a reduction in the level of waterborne receipts occurred and receipts did not begin to rise again until the late 1960's. This reduction occurred in 1964 when two petroleum pipeline companies, Colonial Pipeline and Plantation Pipeline, began delivering petroleum products to the major cities in the southeastern and Middle Atlantic states from the Gulf Coast refineries. In the Bay Region the pipeline delivered products directly to Bay area cities, thus the waterborne receipts into Baltimore and Hampton Roads decreased until the pipelines reached their capacities. The products shipped consisted of gasoline, kerosene, jet fuel, and distillate fuels (referred to as "clean" petroleum products). Waterborne receipts of bulk oil started

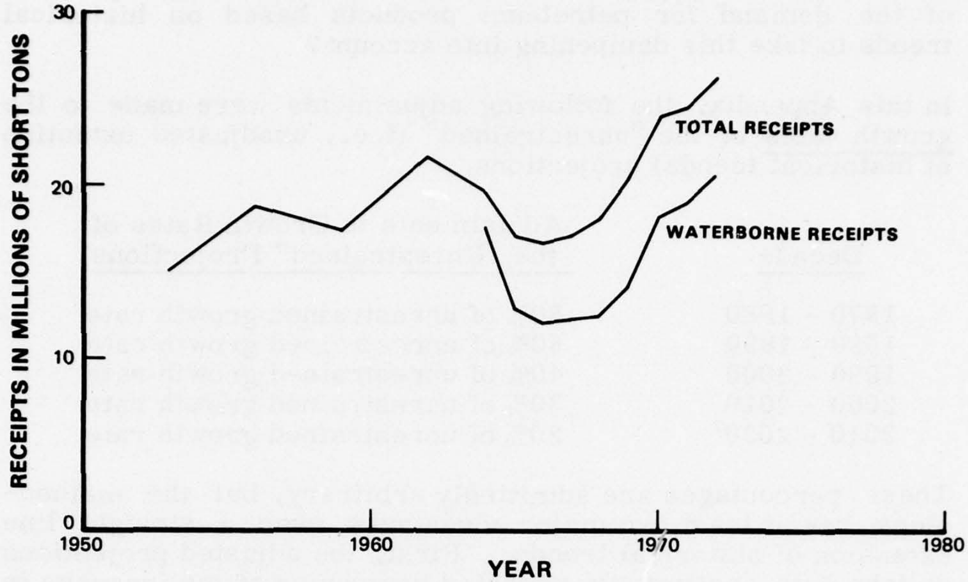

Figure 9-3: BULK OIL RECEIPTS BALTIMORE AND HAMPTON ROADS★

★THIS GRAPH DOES NOT INCLUDE RECEIPTS AT CHESAPEAKE BAY PORTS OTHER THAN HAMPTON ROADS AND BALTIMORE. THE "DIP" IN BOTH TOTAL AND WATERBORNE RECEIPTS DURING THE MIDDLE AND LATE 1960's WOULD NOT EXIST IF WATERBORNE RECEIPTS TO ALL BAY PORTS WERE INCLUDED.

to increase again in 1968 as the pipelines approached their capacities. (It was assumed pipeline capacities were reached by 1972).

In order to estimate the historical demand for bulk oil in a given "distribution area" for a particular port, it was necessary to add pipeline receipts to waterborne receipts into the area (virtually all of the petroleum and petroleum products imported into the Bay area are shipped by w ater or pipeline except for some imports by truck to the Eastern Shore). Once this historical data is calculated, unrestrained projections are developed which are then adjusted according to the methodology discussed above. The final products of this exercise are projections of total demand for the clean bulk oil commodities. At this writing, neither of the two pipeline companies have any plans for expansion in the Chesapeake Bay Area. It was, therefore, assumed that all of the projected increases in demand for these commodities will be absorbed by a corresponding increase in waterborne receipts. These projections of waterborne receipts should, therefore, be considered as being optimistic since any increase in pipeline capacity serving the area will result in a decline in the level of waterborne receipts. The decision to transport petroleum products by pipeline is based on a variety of factors including the cost of transporting by water, the construction cost associated with building or expanding a pipeline, the availability of barges and tankers, and the availability of sufficient refinery capacity at the origin of the pipeline to handle the increased volume. The lowest level of waterborne receipts of "clean" products would theoretically be zero, if expansion of pipeline capacity were to keep pace with increased demand, although there would probably continue to be relatively small amounts arriving by water to help fill orders. Heavier products, most notably residual fuel, are not easily transported by pipeline due to their high viscosity. It is therefore assumed that all residual fuel will continue to be shipped by water into the Chesapeake Bay Region.

BULK COAL AND BULK GRAINS

Bulk coal and bulk grains are basically export items in Chesapeake Bay ports. The projections prepared by Robert R. Nathan Associates, Inc., in Volume II of the Corps of Engineer's U.S. Deepwater Port Study are used as the data basis in this Appendix with some modifications as described in the appropriate sections.

BULK ORE

The methodology used to project bulk ore movements is discussed in the section on Baltimore Harbor.

GENERAL CARGO

Projections were initially made for total foreign general cargo traffic passing through the East Coast ports of the United States by relating general cargo movements to total personal income in the United States during the 1953-1972 period. An excellent statistical relationship exists between these two variables with $R^2 = 0.90$ and the t-value significant at the 99 percent level of confidence. These projections were then allocated to Hampton Roads and Baltimore based on trends in the two port's historical shares of the total East Coast traffic.

PROJECTED DEMANDS

BALTIMORE HARBOR

On a tonnage basis, waterborne commerce moving through Baltimore is dominated by the transport of the bulk commodities as shown in Figure 9-4. Bulk oil, coal, ore, and grain accounted for 77 percent of the total tonnage passing through the Port. Miscellaneous bulk commodities accounted for another 7 percent of the total commerce.

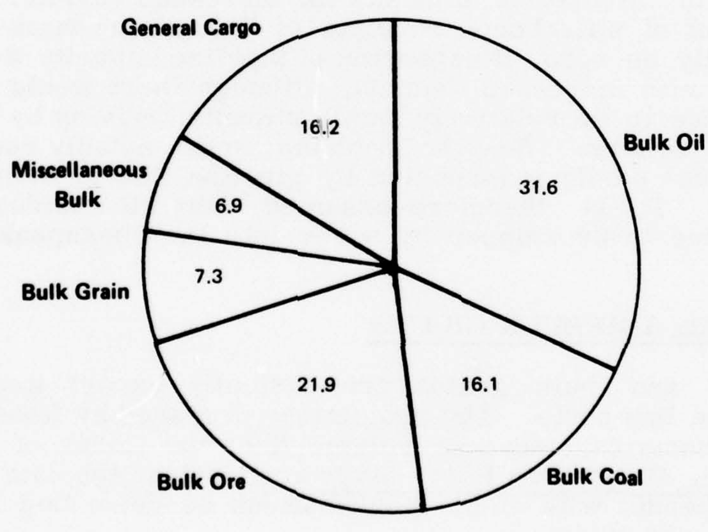

Figure 9-4: COMMODITY DISTRIBUTION OF TOTAL WATERBORNE TRAFFIC THROUGH BALTIMORE HARBOR, 1972 (%)

Baltimore is also heavily oriented towards imports, both foreign and domestic. Foreign imports and domestic receipts together accounted for almost three-quarters of the total traffic movements as shown in Figure 9-5. A large part of this traffic consists of imports and receipts of petroleum products and iron ore. Most of the outbound traffic consisted of foreign exports of coal and grain. The following sections present a detailed analysis of the projection methodology and the actual projections on a commodity group basis.

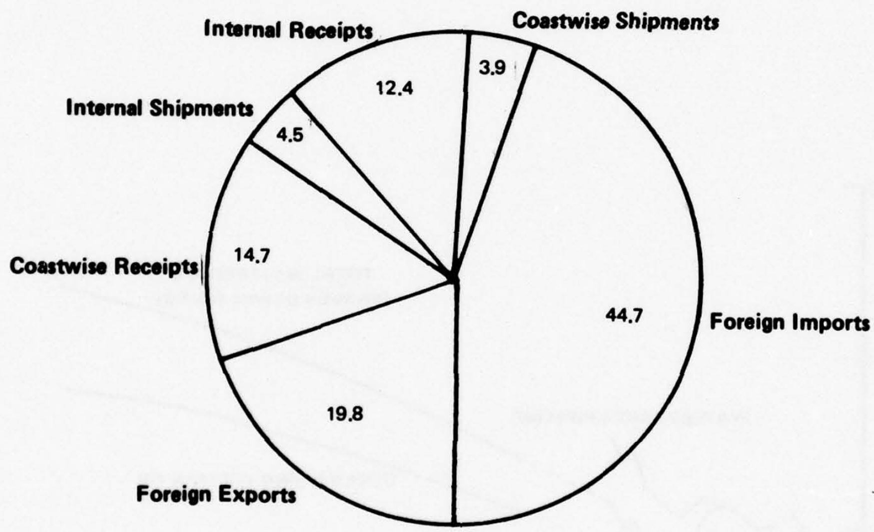

Figure 9-5: DISTRIBUTION OF MAJOR TRAFFIC FLOWS THROUGH BALTIMORE HARBOR IN 1972 (%)

a. Bulk Oil. The industrial, commercial, and residential complex surrounding Baltimore consumes huge amounts of petroleum fuels for heating, processing, and transportation purposes (as shown on Figure 9-6). Bulk oil commodities accounted for 32 percent of the total waterborne traffic and for 16 percent of the foreign commerce moving into and out of the Port in 1972. The most important commodities within the bulk oil group are residual fuel, gasoline, and distillate fuel. Approximately 90 percent of the bulk oil movements were either domestic (57 percent) or foreign imports (33 percent). The remainder are internal barge shipments, mostly to points within Chesapeake Bay. The bulk oil distribution area for Baltimore consists, generally speaking, of the entire Baltimore Economic Area plus the York, Pennsylvania, SMSA, although the area varies somewhat according to the type of commodity. Figure 9-6 also illustrates the total bulk oil projections for Baltimore. The following is a breakdown of the projections for the important commodities within the bulk oil category.

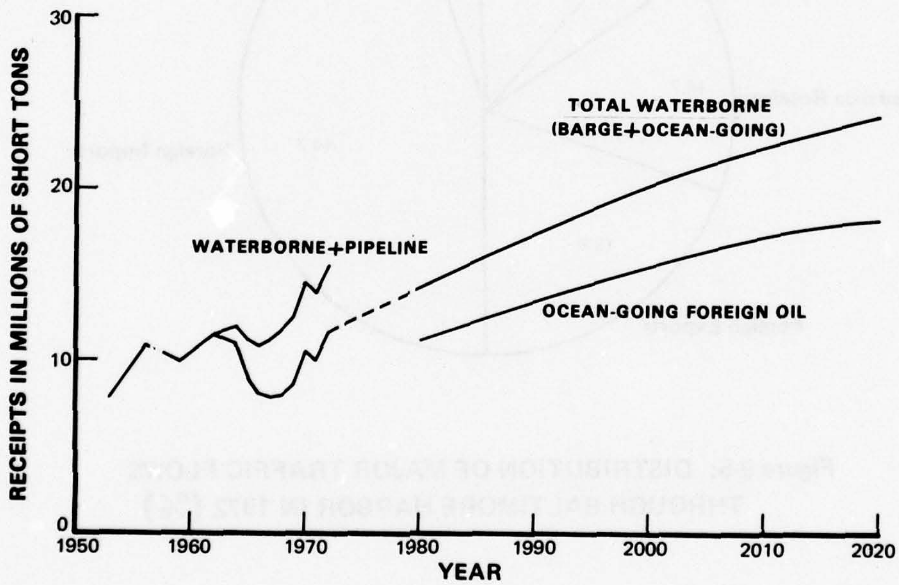

Figure 9-6: BALTIMORE HARBOR BULK OIL - TOTAL RECEIPTS HISTORICAL AND PROJECTED

(1) Residual fuel. In 1972, roughly 5.5 million short tons of residual fuel were shipped into Baltimore by water. Residual fuel is used by industry, power plants, large commercial establishments, and government for heating and processing purposes. In addition, relatively small amounts are used as bunker fuel. Residual fuel has remained competitive with other fuels in the Chesapeake Bay Region, as well as most of the East Coast, because of the availability of navigation facilities to handle the less expensive foreign residuals and because of more stringent air quality regulations which restricted the use of high-sulfur coal. Figure 9-7 shows waterborne imports of residual fuel into Baltimore. In 1972, roughly 90 percent of these inbound shipments originated in Venezuela or the Caribbean Islands (including the Virgin Islands). Vessels on these trade routes generally average between 25-55,000 deadweight tons (dwt) with up to 39-foot drafts. Although the Exxon Company uses vessels up to 75,000 dwt with 42-foot drafts, the larger vessels are not able to load to full capacity due to depth limitations. There were no pipeline movements of residual fuel into Baltimore during the period of record.

The sharp increases in movements since 1968, shown in Figure 9-7, are the result of power plants switching from coal to residual oil in order to meet the more stringent air quality standards. Most of the tidewater power plants in the Baltimore distribution area have been converted to residual fuel. The Baltimore Gas and Electric Company (BG&E) is, by far, the largest user of residual fuel for the purpose of generating electricity in the area. BG&E power plants used approximately 1.7 million short tons of residual fuel in 1972. For projection purposes, it was assumed that this amount would decline steadily as older fossil fuel burning plants are replaced by more efficient fossil fuel burning or nuclear plants. By the year 2000 the use of residual fuel by power plants was projected to be approximately 25 percent of the 1972 figure.(22) After 2000, power plant use was assumed to decline to zero by the year 2020.

To project future movements of residual fuel into Baltimore for uses other than power plants, it was assumed that all receipts during the 1953-1968 period (prior to the power plant conversion) were for non-power plant uses. Receipts during this period were then correlated with total income during the same period. Projections were then calculated to the year 2020 using this statistical relationship as a base. The regression was forced through the estimated non-power plant use of 3.75 million short tons in 1972. The two projections were then combined to produce the total projection for residual fuel as presented in Figure 9-7. The projected rate of increase averages 0.75 percent annually for the 1972-2000 period.

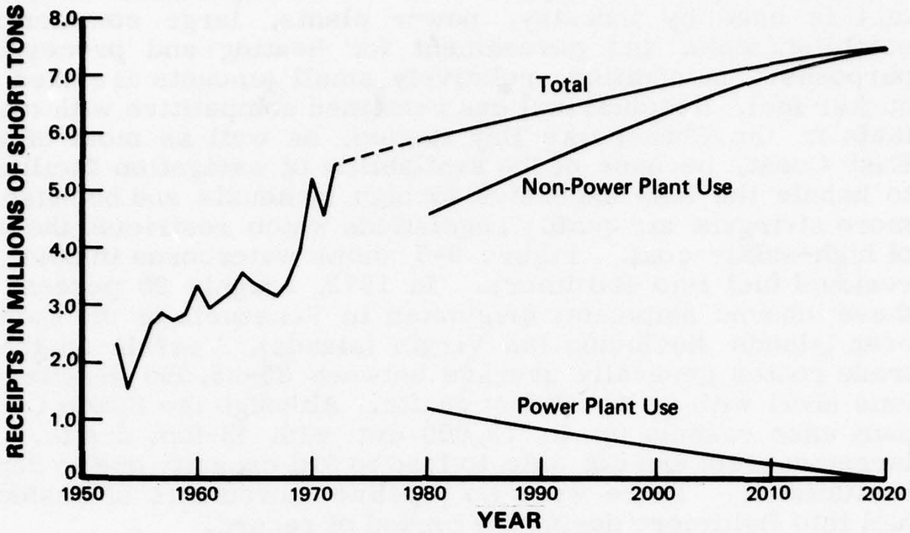

Figure 9-7: BALTIMORE HARBOR TOTAL RECEIPTS- RESIDUAL FUEL

The validity of these projections depends, in large part, on government air quality standards and energy policy. If air quality standards are relaxed, or if Federal energy policy favors the use of coal, most power plants could quickly convert back to coal if the conversion is found to be economical. Power plant demand for residual fuel could also be influenced by the development of economical techniques to de-sulfurize coal or to remove the sulfur from the smoke created by the burning coal.

(2) Gasoline. Approximately 2.6 million short tons of gasoline were shipped into Baltimore by water in 1972. The major users of gasoline in the distribution area are automobiles, trucks, and buses. Virtually all of the gasoline shipped into Baltimore was classified as domestic receipts. Approximately two-thirds were coastwide receipts, originating mainly in the Virgin Islands and at the Gulf Coast refineries. The remainder of the inbound gasoline is shipped to Baltimore by barge from the refineries along the Delaware River and from the Hampton Roads-York River, Virginia, areas. Tankers from the Virgin Islands are in the 30-55,000 dwt range with 39-foot drafts. Tankers moving gasoline from the Gulf Coast to Baltimore, mostly for Exxon, range in size up to 75,000 dwt with 42-foot drafts. The larger vessels must arrive partially loaded due to depth limitations both in Baltimore and the the Gulf Coast.

As shown in Figure 9-8, waterborne receipts of gasoline rose steadily during the period between 1953 and 1963. In 1964, however, waterborne movements into Baltimore exhibited a strong downward trend until 1966. This downward trend coincided with the initiation of the Colonial Pipeline Company's service to the Baltimore area. Waterborne receipts began to increase steadily once again in 1970 as the pipeline approached its physical capacity. Adding pipeline receipts to waterborne receipts reveals a fairly constant increase in the demand for gasoline in the Baltimore distribution area. This increase averaged about 4.25 percent annually during the 1953-1972 period.

In projecting inbound movements of gasoline to Baltimore, the best statistical results were achieved when receipts were correlated with total income in the Baltimore distribution area. Projected rates of increase average slightly under 3.5 percent per year over the 1972-2000 period.

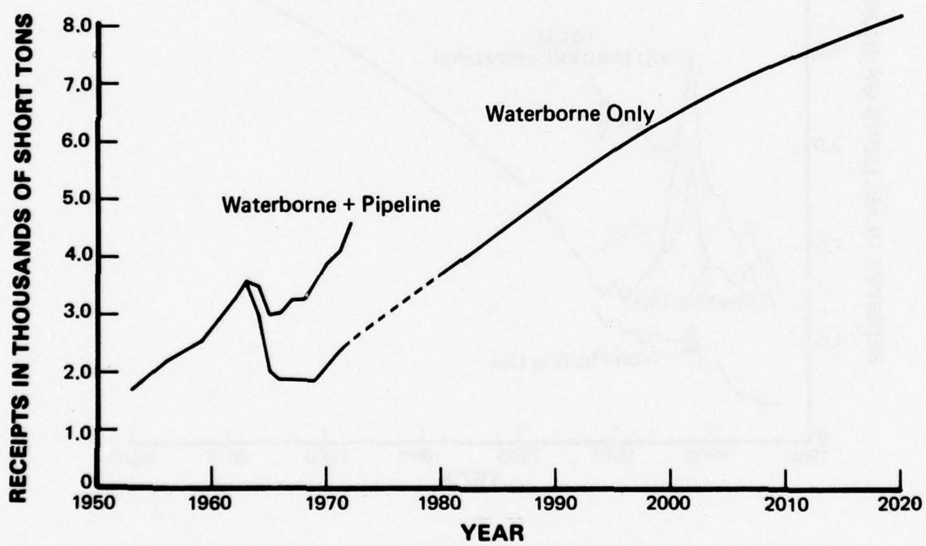

Figure 9-8: BALTIMORE HARBOR TOTAL RECEIPTS - GASOLINE

(3) Distillate fuel. In 1972, slightly over 1.6 million short tons of distillate fuel were shipped by water into Baltimore. The major use of distillate in the Baltimore distribution area is for heating purposes, mostly in homes but also in commercial establishments, industries, and government buildings. There are numerous other users of this type of fuel including diesel-powered trucks, buses, and other vehicles, peak load power plants, and industries for processing purposes. Figure 9-9 shows inbound movements of distillate fuel into Baltimore during the 1953-1972 period. Virtually all of the waterborne receipts were from domestic sources in 1972, mainly the Virgin Islands, the Gulf Coast, and the Delaware River refineries. Vessels transporting distillate fuel are similar in size to those handling gasoline.

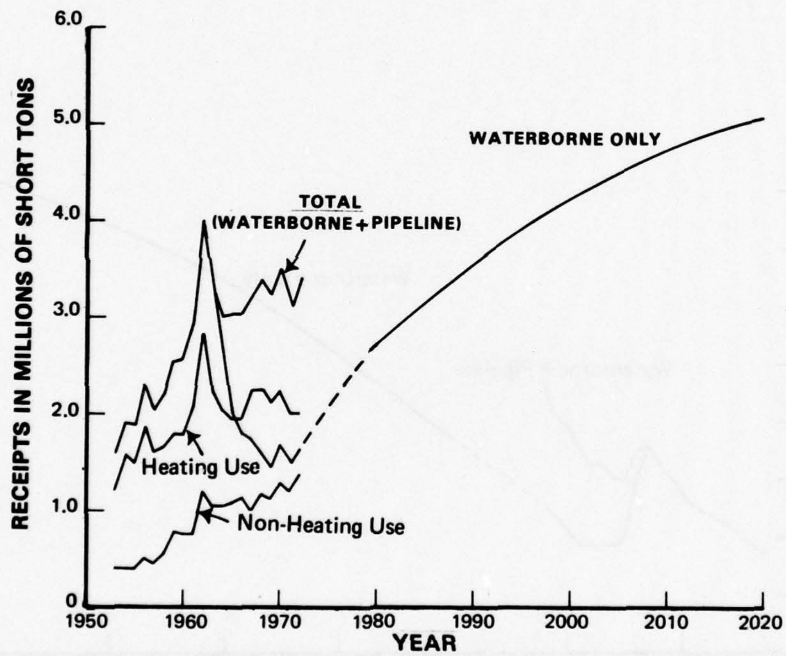

Figure 9-9: BALTIMORE HARBOR RECEIPTS - DISTILLATE FUEL

Based on data on sales of distillate fuel oil by use in the State of Maryland(23), estimates were made of the amounts of fuel oil used for both heating and purposes other than heating in the Baltimore distribution area during the 1953-1972 period. Receipts of distillate used for heating purposes during this period were highly related to the number of home oil burners in use in the distribution area after adjusting for the severity of the winter by adding annual degree days to the regression equation. Forecasts of the numbers of oil burners in use were made by extending the 20-year historical relationship between the number of oil burners and population to the year 2020. These forecasts were then used to project total receipts of distillate fuel oil used for heating purposes.

Most of the remainder of the distillate oil receipts (about 70 percent) were used by diesel-powered vehicles and peak load power plants. These movements were correlated with total income in the distribution area. The two projections were then combined to derive a total projection for distillate fuel shipped into Baltimore (see Figure 9-9). The rate of increase for waterborne receipts averages slightly under 3.5 percent for the 1972-2000 period.

(4) Crude Oil. In 1972, crude oil receipts totaled slightly over 800,000 short tons. All inbound movements of crude oil were by water. These movements originated in Venezuela and the Mid-East and were used by several asphalt refining plants located in the Baltimore Harbor area. As shown in Figure 9-10, receipts of crude oil exhibited a sharp decline in the 1956-58 and 1963-65 periods coinciding with reductions in crude oil refining capacity in the distribution area. In 1972, however, there was a slight increase in capacity. Virtually all of the asphalt produced by these plants is used in the construction industry, especially in the paving of roads and the production of shingles. Projections of crude oil receipts at Baltimore are based on the OBERS projections of output in the petroleum refining industry in the Baltimore SMSA. Because of a lack of complete historical earnings data for the petroleum refining industry in the Baltimore SMSA area, an analysis of the historical relationship between crude oil receipts and output in this industry was not possible. As a result, the crude oil input/refinery output relationship was assumed to remain constant to the year 2020 in the base projections.

Tankers carrying crude oil into Baltimore are in the 20-30,000 dwt range with 32 to 35-foot drafts. These vessels are very small by world tanker fleet standards where vessels well over 150,000 dwt are not at all uncommon. However, due to the relatively small volumes of crude oil projected to enter Baltimore, it is unlikely that there will be any significant increase in vessel size in the future.

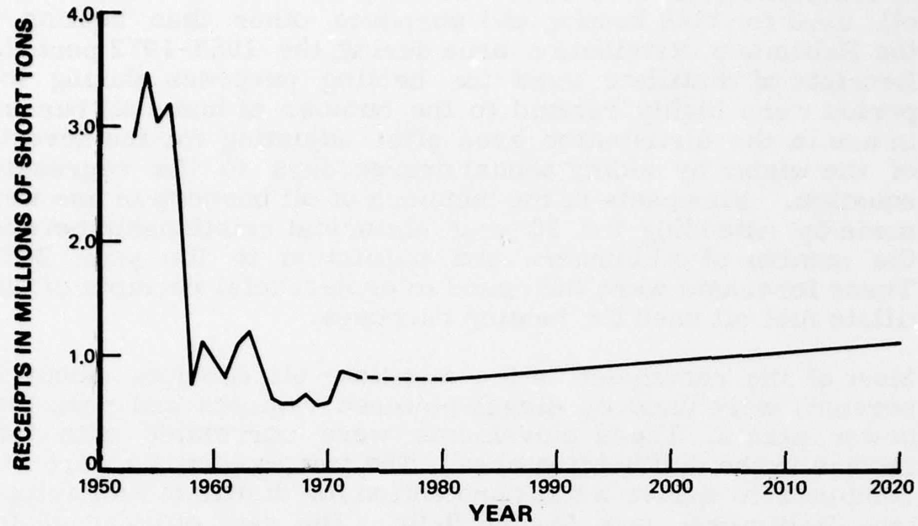

Figure 9-10: BALTIMORE HARBOR TOTAL RECEIPTS - CRUDE PETROLEUM

(5) Miscellaneous bulk oil. This category includes jet fuel, kerosene, asphalt, and miscellaneous petroleum products. *Approximately 1.0 million short tons of miscellaneous* bulk oil products were received at Baltimore by water in 1972. About one-quarter of these receipts consisted of foreign imports of kerosene from the Caribbean area. The remainder of the inbound waterborne traffic was domestic in origin. Waterborne movements of miscellaneous bulk oil commodities are primarily by barge or small tankers. As shown in Figure 9-11, waterborne receipts exhibited the characteristic dip starting in 1964 reflecting the fact that jet fuel and kerosene are "clean" fuels and large quantities are transported into Baltimore by pipeline. Asphalt receipts averaged about 50 percent of total inbound waterborne shipments in this cateogry during the last several years. Most asphalt is used on roads and in building materials such as shingles. Kerosene, which comprised about 30 percent of total receipts in 1972, is used in space heaters, lamps, tractors, and cooking stoves. Kerosene has met stiff competition in recent years from bottled propane gas in the heating market. Total (i.e., pipeline plus waterborne) jet fuel shipments have shown steady increases since 1960 and are expected to continue to increase as the demand for air transportation increases. Historical receipts of miscellaneous bulk oil products were correlated with total income in the Baltimore

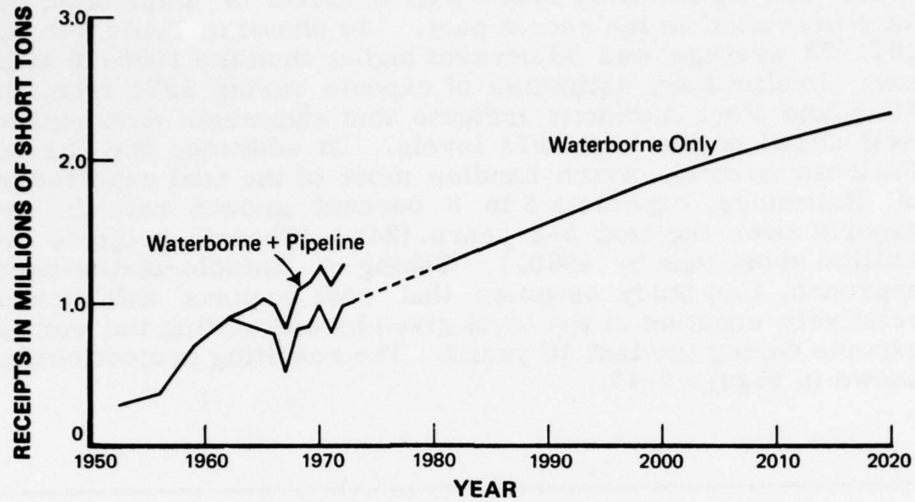

Figure 9-11: BALTIMORE HARBOR RECEIPTS - MISCELLANEOUS BULK OIL PRODUCTS

distribution area. The projected rate of increase for the 1972-2000 period was about 2.25 percent annually.

b. Bulk Coal. In 1972, approximately 3.8 million short tons of coal were exported through the Port of Baltimore, making coal the largest single export commodity for the Port. Bulk coal accounted for about half of the total foreign exports leaving Baltimore during that year. Approximately 90 percent of the coal shipped out of Baltimore is used in the production of coke for foreign steel industries. Because of its proximity to the rich Appalachian coal fields in northern West Virginia and Pennsylvania, Baltimore is in a strong competitive position with respect to the U.S. export coal trade. The fields served by Baltimore are not as productive as the fields immediately to the south, which are served by Hampton Roads, and explains why Baltimore's exports are significantly less than those of the Virginia Port complex. In 1972, slightly over 60 percent of the exports were shipped to Japan. West Germany and the United Kingdom accounted for an additional 13 and 9 percent, respectively. Most of the coal shipped to West Germany was used in the generation of electricity. That country was the only one to import steam coal from the U.S. in significant quantities.

Robert R. Nathan Associates, in the Deepwater Port Study, made predictions of export coal out of Baltimore for 1980 and 2000 (see Figure 9-12 and Table 9-1). These projections, however, are significantly lower than the level of shipments that have prevailed in the recent past. As shown in Table 9-1, the 1971-73 average was 36 percent higher than the 1965-70 average. Preliminary estimates of exports during 1974 from the Maryland Port Authority indicate that shipments were running well ahead of the high 1973 levels. In addition, the Chessie Railroad System, which handles most of the coal exported out of Baltimore, expects a 5 to 8 percent growth rate in coal exports over the next 5-8 years. (24) (Chessie projects 6.8 million short tons by 1980.) Taking a "middle-of-the-road" approach, this Study assumes that coal exports will remain relatively constant at the level given by calculating the average exports during the last 10 years. The resulting projections are shown in Figure 9-12.

TABLE 9-1
BALTIMORE COAL EXPORTS, HISTORICAL AND PREDICTED
(Thousands of Short Tons)

	1965-70 Average	1971-73 Average	Nathan Associates* 1980	Nathan Associates* 2000
Export Coal	2,843	3,866	2,150	1,050

* Nathan's projections, which were prepared for coking coal only, were adjusted to take into account Baltimore's projected steam coal exports of 500,000 short tons. (25)

The average vessel exporting coal out of Baltimore is in the 35-55,000 dwt range with 37 to 42-foot drafts, although bulk coal carriers up to 120,000 dwt with 47-foot drafts have called on the Port. World fleet dry bulk carriers will probably level off in the 150-200,000 dwt range with drafts of about 55 feet.

Although the level of export coal shipments in the future is expected to remain relatively constant, the destinations of the coal will probably change significantly. Japan, by far the present leader in the importing of U.S. coal, will demand a smaller portion of the total exports. On the other hand, Western Europe will increase its share of U.S. exports.

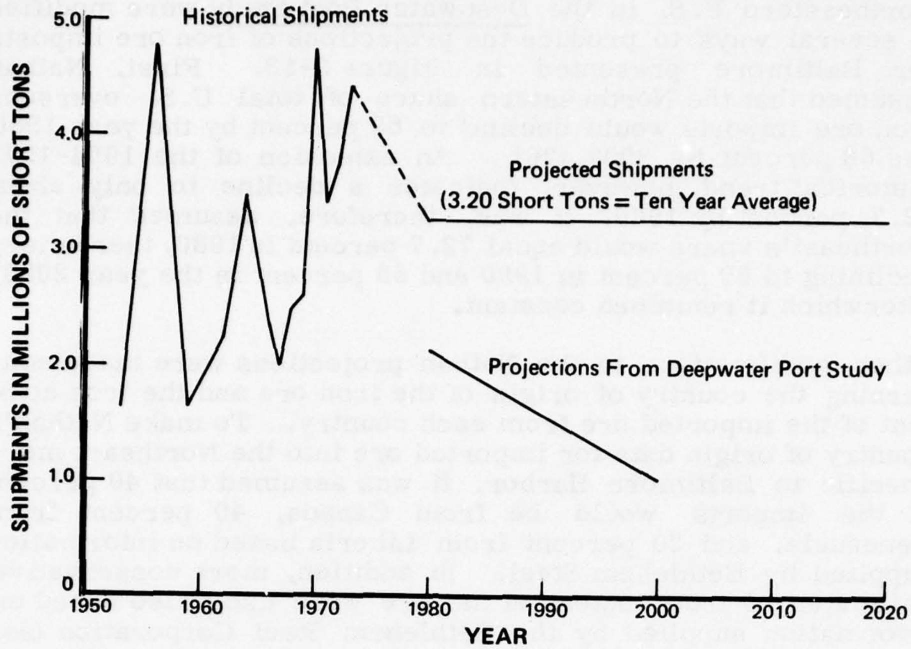

Figure 9-12: BALTIMORE HARBOR BULK COAL EXPORTS

In addition to foreign exports of coal, there are also signifinificant volumes of coking coal shipped by barge from Hampton Roads to the Bethlehem Steel Plant in Baltimore. These shipments totaled 2.8 million short tons in 1972.

c. Bulk ore. The Baltimore area's large primary metals industry demands considerable quantities of metallic ores every year. There were slightly over 9.0 million short tons of metallic ores shipped into Baltimore in 1972. This quantity comprised 49 percent of the total foreign imports coming into the Port. Baltimore's primary metals industry is dominated by the Bethlehem Steel Corporation which employs roughly three-quarters of the workers in the primary metals sector. Consequently, most of the metallic ore imports, about 93 percent in 1972, consisted of iron ore used in the production of steel. Approximately 37 percent of the imports in 1972 originated in Venezuela, with Canada (31 percent) and Liberia (20 percent) also supplying significant quantities. Aluminum, manganese, chromium, and other nonferrous ores and concentrates comprise the remaining 7 percent of metallic ore imports.

The Nathan Associates projections of iron ore imports for the Northeastern U.S. in the Deepwater Port Study were modified in several ways to produce the projections of iron ore imports for Baltimore presented in Figure 9-13. First, Nathan assumed that the Northeastern share of total U.S. overseas iron ore imports would decline to 69 percent by the year 1980 and 68 percent by 2000. (26) An extension of the 1954-1973 historical trend, however, indicates a decline to only about 72.7 percent by 1980. It was, therefore, assumed that the Northeast's share would equal 72.7 percent in 1980, thereafter, declining to 69 percent in 1990 and 68 percent in the year 2000, afterwhich it remained constant.

Other modifications to the Nathan projections were made concerning the country of origin of the iron ore and the iron content of the imported ore from each country. To make Nathan's country of origin data for imported ore into the Northeast more specific to Baltimore Harbor, it was assumed that 40 percent of the imports would be from Canada, 40 percent from Venezuela, and 20 percent from Liberia based on information supplied by Bethlehem Steel. In addition, more conservative estimates of iron content of the ore were used also based on information supplied by the Bethlehem Steel Corporation (see Table 9-2).

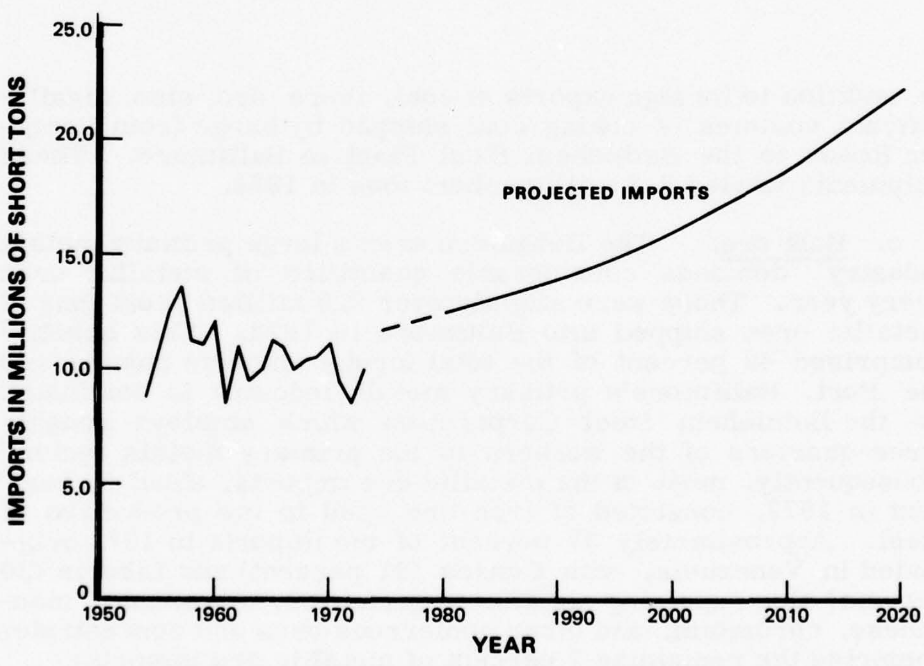

Figure 9-13: BALTIMORE HARBOR IRON ORE IMPORTS

TABLE 9-2
PROJECTED IRON CONTENT OF IMPORTED IRON ORE ENTERING NORTHEASTERN PORTS
(Percent)

	Nathan Associates[1]	Revised for this Report[2]
Canada		
1980	66%	60%
1990	70%	63%
2000	75%	68%
Venezuela		
1980	70%	62%
1990	75%	65%
2000	80%	68%
West Africa (including Liberia)		
1980	65%	62%
1990	68%	65%
2000	70%	68%

[1] Source: U.S. Deepwater Port Study, "Commodity Studies and Projections," p. 136.
[2] Based on data received from the Bethlehem Steel Corporation.

Projections were prepared for Baltimore Harbor by disaggregating the modified Nathan projections for the Northeastern ports based on an analysis of Baltimore's historical share of the total. There have been several developments during the last 20 years which significantly altered Baltimore's share of the iron ore passing through the Northeast (see Figure 9-14). First, during the early 1950's, the Pennsylvania Railroad (now Penn Central) constructed a large ore depot on the Delaware River below Philadelphia to ship imported ore to steel mills at inland locations. Second, during the mid-1950's the St. Lawrence Seaway opened. The new Seaway provided a direct route to the Great Lake's steel mills for oceangoing vessels. Third, the U.S. Steel Corporation opened a plant on the Delaware River near Fairless, Pennsylvania, in the early 1960's which not only consumed iron ore at Fairless but also

shipped large volumes of ore inland. These developments had the effect of diverting significant quantities of iron ore (as well as other types of metallic ores) which had once passed through Baltimore on its way to inland plants to the Delaware River and St. Lawrence Seaway. During the last 10 years, imports have averaged approximately 45.2 percent. It is assumed to remain at approximately that level throughout the projection period (see Figure 9-14).

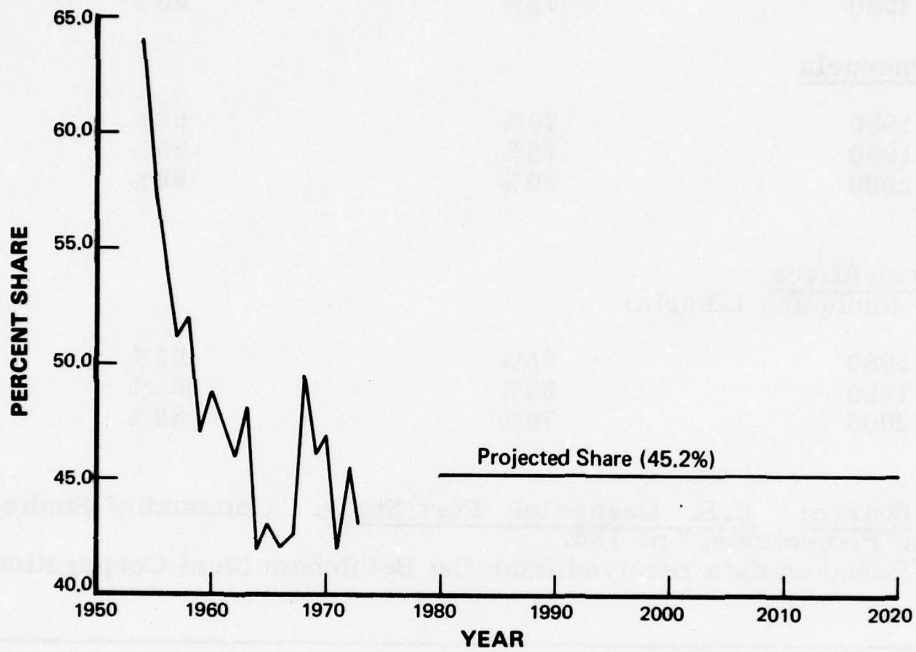

Figure 9-14: BALTIMORE'S SHARE OF NORTHEASTERN IRON ORE IMPORTS

The ships carrying iron ore into Baltimore are the largest that call on the Port. The average iron ore vessel is in the 40-60,000 dwt range with 38 to 42-foot drafts. Vessels of this size use the existing 42-foot channel to the maximum extent. There are occasionally dry bulk vessels over 100,000 dwt which call at Baltimore partially loaded with iron ore. The largest ship ever to call on the Port was a 134,000 dwt vessel which unloaded approximately 84,000 tons of iron ore from Brazil. The future world fleet of dry bulk vessels carrying iron ore will probably level-off in the 150,000-200,000 range with drafts of about 55 feet.

The non-ferrous ores imported into Baltimore are used primarily by Bethlehem Steel in the production of various types of steel and several other major primary metals industries engaged in the production of aluminum and copper. As shown in Figure 9-15, imports of non-metallic ores at Baltimore were reduced significantly by the diversion of ore to the Delaware River and the St. Lawrence Seaway. During the 1953-72 period, the volume of imports fell by almost 4 million short tons. The projections presented in Figure 9-15 are based on the assumption that the movement trends for non-ferrous ore will reverse and begin to increase at the same rate as the iron ore imports. The vessels carrying nonferrous ores are significantly smaller than those handling iron ore because of the much smaller volumes of material involved. Most of the ships are in the 20-40,000 dwt range with 32 to 36-foot drafts. There is probably some minor potential for growth in vessel size in the future as the volume of imports increases.

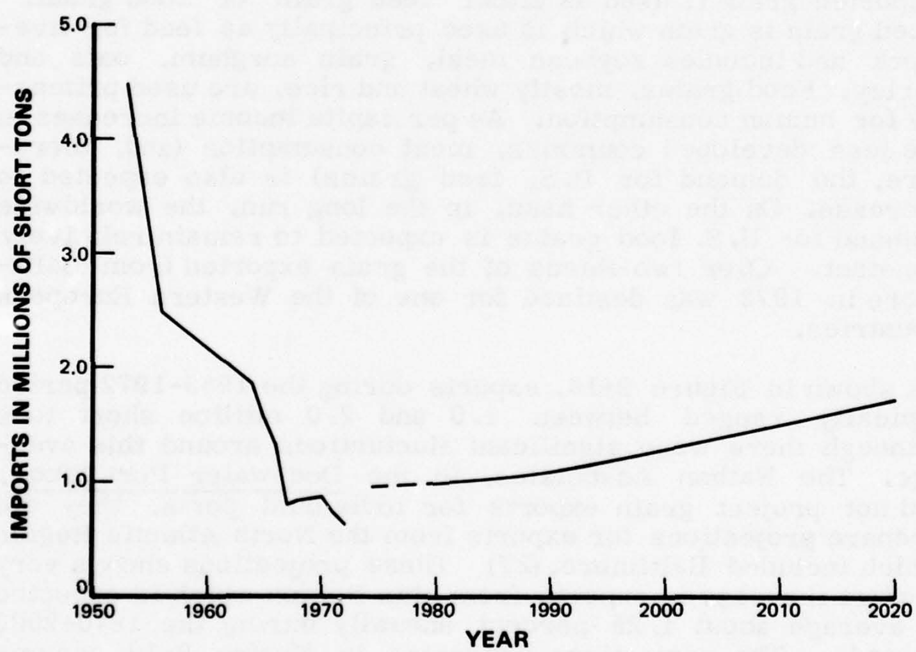

Figure 9-15: BALTIMORE HARBOR IMPORTS - NON-FERROUS ORES

d. Bulk Grain. The Port of Baltimore grew to national prominence during the late 18th and early 19th centuries through the exporting of grain. During this period the States of Maryland, Pennsylvania, and Virginia were considered to be the "breadbasket" of the United States. Since that time, however, grain cultivation has spread westward into the fertile plains of the Midwest and Northwest. Most of the grain grown in these areas is presently exported through ports in the Northwest, Gulf Coast, and Great Lakes. Baltimore continued to handle much of the grain produced in the upper Midwest until 1956 when the St. Lawrence Seaway opened allowing the Great Lakes' ports to syphon the majority of this trade away from Baltimore and the other East Coast ports. Most of the grain presently exported through Baltimore is still grown in the Midwest, especially Ohio and Indiana, where it is bought by one of the large companies owning grain elevators in Baltimore and shipped east to the Port for export.

In 1972, Baltimore exported approximately 2.9 million short tons of grain, although the average annual export for the last 5 years of record was only 1.5 million short tons. The major types of grain exported in 1972 were corn (45 percent), soybeans and soybean meal (40 percent), and wheat (13 percent). Exported grain is used as either "feed grain" or "food grain." Feed grain is grain which is used principally as feed for livestock and includes soybean meal, grain sorghum, oats and barley. Food grains, mostly wheat and rice, are used primarily for human consumption. As per capita income increases in the less developed countries, meat consumption (and, therefore, the demand for U.S. feed grains) is also expected to increase. On the other hand, in the long run, the worldwide demand for U.S. food grains is expected to remain relatively constant. Over two-thirds of the grain exported from Baltimore in 1972 was destined for one of the Western European countries.

As shown in Figure 9-16, exports during the 1953-1972 period typically ranged between 1.0 and 2.0 million short tons although there were significant fluctuations around this average. The Nathan Associates, in the Deepwater Port Study, did not project grain exports for individual ports, they did prepare projections for exports from the North Atlantic Region which included Baltimore. (27) These projections show a very modest increase in exports from this Region which is expected to average about 1.25 percent annually during the 1970-2000 period. The projections presented in Figure 9-16 assume that exports through Baltimore will increase at the same rate as total exports from the North Atlantic ports. This trend was extended to the year 2020. The mix of grains in the future

is expected to remain the same as the present mix. (28) Because of the relatively small volumes of grain exported through Baltimore, the average size vessel calling on the Port for grain (i.e., 15-30,000 dwt with 28 to 35-foot drafts) is significantly smaller than the standard world fleet grain carriers. Occasionally, however, much larger vessels enter the Port. For example, in June of 1974 a 102,000 dwt grain carrier loaded in Baltimore. The vessel was only able to load 60,000 tons of cargo, however, due to channel depth limitations.

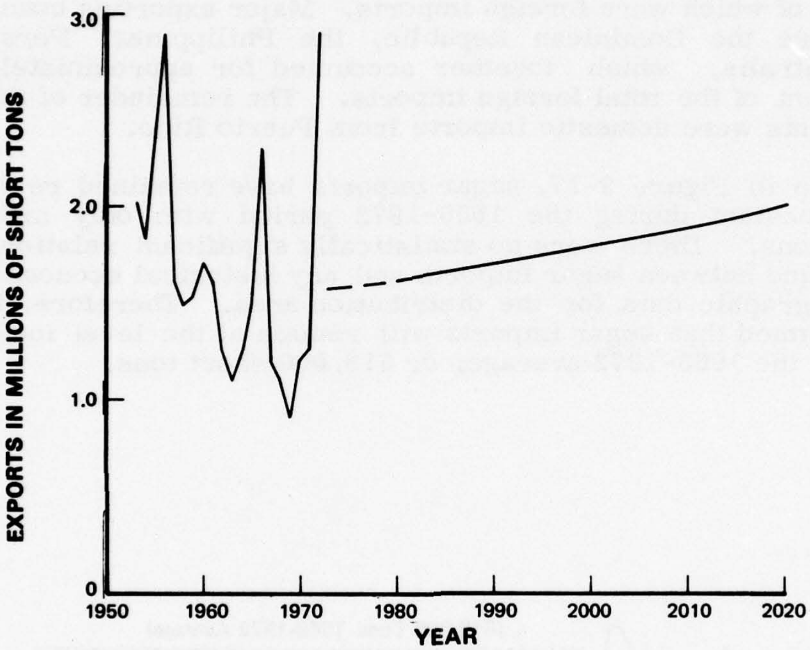

Figure 9-16: BALTIMORE HARBOR FOREIGN EXPORTS - BULK GRAIN

e. Miscellaneous bulk. The miscellaneous bulk category for Baltimore Harbor contains such commodities as gypsum, sugar, salt, molasses, sulfuric acid, and fertilizer products. In 1972, there were slightly over 3.0 million short tons of miscellaneous bulk traffic to and from the Port of Baltimore. This amounted to about 7 percent of the total commerce in the Port. Approximately 72 percent of this traffic was foreign imports with an additional 17 percent classified as domestic imports. Practically all of these inbound movements were raw

or partially processed materials shipped to Baltimore for further processing by factories in the Port area. (29) These types of commodities are especially important to the local economy because the processing activities generate jobs and income. The following sections will present projections for the important commodities within the miscellaneous bulk category.

(1) Sugar. Raw sugar is imported into Baltimore by the largest tidewater sugar refinery in the world where it is processed for human consumption and distributed into the Mid-Atlantic, Southeastern, and Midwestern states. In 1972, there were 641,000 short tons of sugar shipped into Baltimore, 82 percent of which were foreign imports. Major exporting countries were the Dominican Republic, the Philippines, Peru, and Australia, which together accounted for approximately 86 percent of the total foreign imports. The remainder of the movements were domestic imports from Puerto Rico.

As shown in Figure 9-17, sugar imports have remained relatively constant during the 1953-1972 period with only mild fluctuations. There were no statistically significant relationships found between sugar imports and any historical economic or demographic data for the distribution area. Therefore, it was assumed that sugar imports will remain at the level indicated by the 1968-1972 average, or 618,000 short tons.

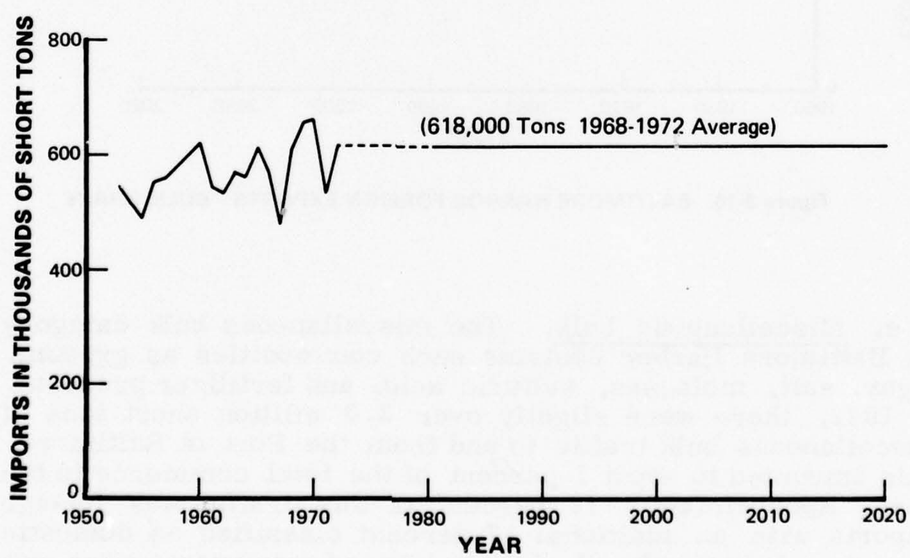

Figure 9-17: BALTIMORE HARBOR MISCELLANEOUS BULK - SUGAR

Vessels importing sugar into Baltimore average in the 10-32,000 dwt range with 27 to 37-foot drafts. The larger vessels must be light-loaded due to depth limitations.

(2) Gypsum. Gypsum is used by several firms in the Baltimore area in the production of wallboard and other building material products. These products are then distributed throughout the Middle Atlantic States. The demand for these products is generally related to the level of construction activity. In 1972, just over 700,000 short tons of gypsum were shipped into Baltimore. Virtually all of these movements were foreign imports from Canada. Average vessel size is in the 10-18,000 dwt range with 25 to 31-foot drafts. Gypsum movements are listed under limestone in the Waterborne Commerce Statistics publication.

Historical movements showed a sharp jump between 1962 and 1964 as shown in Figure 9-18. This jump corresponded with the opening of a large gypsum processing plant in Baltimore. While there was a relatively good statistical relationship between population and gypsum receipts during the 1953-1972 period, the resulting projections were felt to be too optimistic because of the influence on the historical data of the plant opening. Consequently, it was assumed that gypsum receipts in the future would increase at the same rate as population in the distribution area.

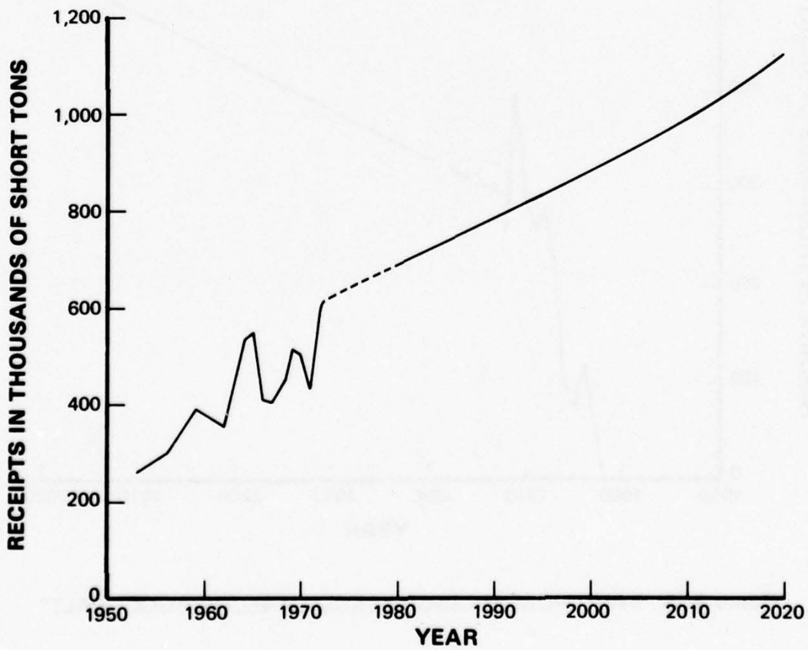

Figure 9-18: BALTIMORE HARBOR MISCELLANEOUS BULK - GYPSUM

(3) Salt. The salt imported into Baltimore is used primarily as road salt during the winter in the metropolitan area, with relatively small quantities used for recharging water softening equipments and other miscellaneous uses. The demand for this type of salt is related in the long run to total road mileage and in the short run to weather conditions.

Prior to 1964, rock salt was transported into the Baltimore area from New York State by truck and rail (see Figure 9-19). In 1964, the distributors in the area started importing cheaper "solar" salt from the Caribbean area. In 1972, slightly over 250,000 short tons of salt were shipped into Baltimore, virtually all from Mexico and the Bahamas. Vessel sizes range between 15-35,000 dwt with 30 to 35-foot drafts. The projections presented in Figure 9-19 assume that salt imports will increase at the same rate as population in the Baltimore SMSA. This assumption was made for reasons basically the same as those given in the discussion on gypsum above.

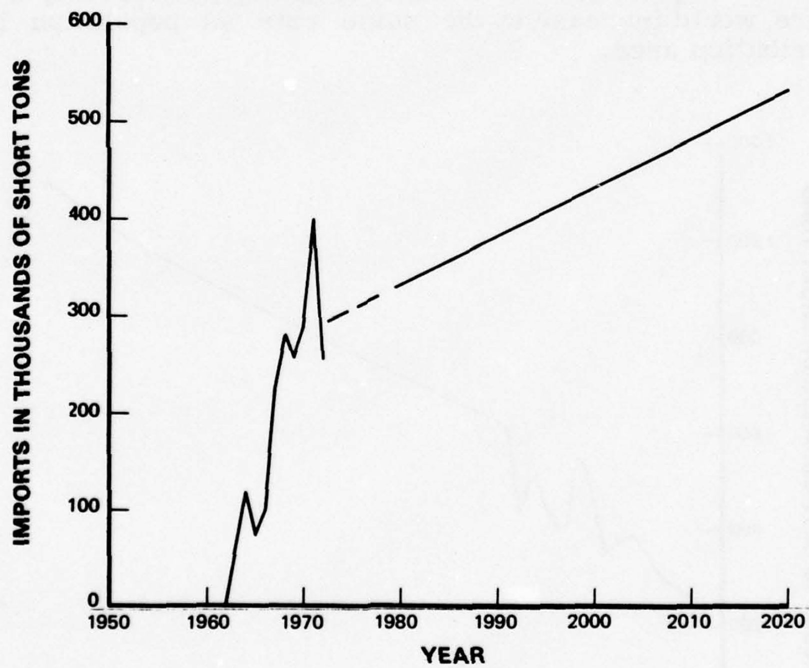

Figure 9-19: BALTIMORE HARBOR MISCELLANEOUS BULK - SALT

(4) Residual miscellaneous bulk. This breakdown includes all commodities in the miscellaneous bulk category except sugar, gypsum, and salt. In 1972, total traffic totaled slightly under 1.3 million short tons. About 60 percent of this commerce consisted of foreign movements of molasses, nonmetallic minerals, fertilizer materials, coke, and solvents. Most of the remaining movements consisted of coastwise and internal barge movements of sulfuric acid, liquid sulfur, and building cement.

As shown in Figure 9-20, shipments of miscellaneous bulk commodities have dropped significantly since the mid-1950's. This is due in large part to a sharp decline in fertilizer receipts (including phosphate rock and superphosphate) over the period. There are several reasons for this decline. First, there were several major fertilizer plant closings in the Baltimore area during the late 1950's and late 1960's. Second, rail rates from the Florida phosphate fields are very competitive with barge rates from that area, but the railroad is faster. As a result, area fertilizer companies using phosphates have, in recent years, been transporting the raw material by rail. Fertilizer receipts are projected to be insignificant during the projected period.

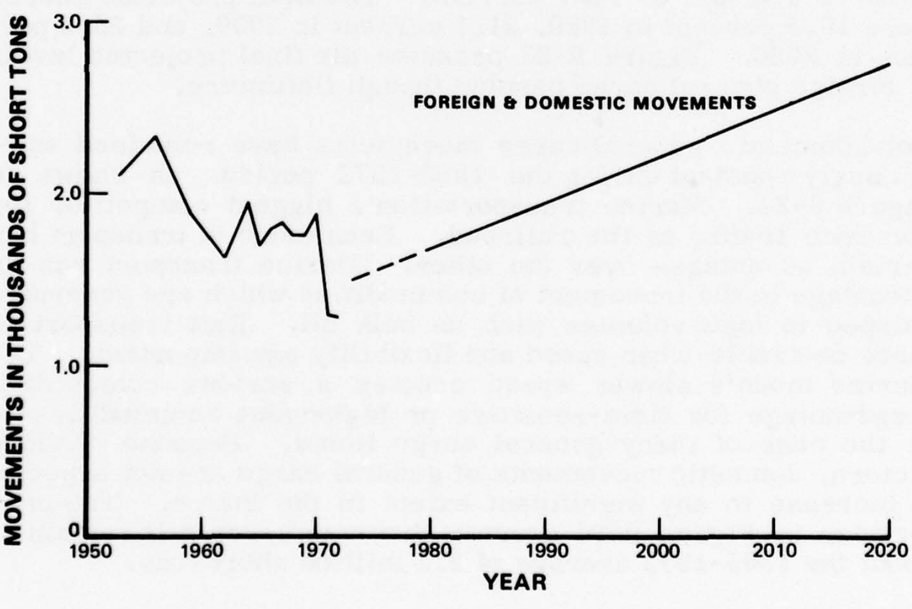

Figure 9-20: BALTIMORE HARBOR - RESIDUAL MISCELLANEOUS BULK

Foreign traffic was projected using an extension of the 1953-1972 time trend, minus fertilizer receipts. It was projected to increase by an annual rate of 2.75 percent during the 1972-2000 period. Domestic movements (i.e., coastwise plus internal) were assumed to remain constant at the 20-year historical average of 820,000 short tons.

f. General Cargo: General cargo commodities accounted for about 16 percent, or 6.7 million short tons, of the total commerce passing through the Port of Baltimore in 1972. Approximately two-thirds of the total general cargo commerce was foreign in origin or destination. An additional 19 percent of the total was classified as coastwise shipments. The major general cargo commodities shipped through Baltimore are listed in Table 9-3.

The Port of Baltimore serves a general cargo market in the United States which extends into the Midwest as far as Chicago, Milwaukee, and St. Louis. Using the methodology discussed in Chapter II, Baltimore's share of the total East Coast foreign general cargo trade (see Figures 9-21 and 9-22) was projected to increase from 14.4 percent in 1972 to 18.3 percent in 1980, 27.4 percent in 2000, and 35.7 percent in the year 2020. Since these projections were considered to be too optimistic, they were adjusted downward by assuming the actual percentage share will be midway between those projected above and the 1970-72 average of 14.7 percent. The final projected shares were 16.5 percent in 1980, 21.1 percent in 2000, and 25.2 percent in 2020. Figure 9-23 presents the final projected levels of foreign general cargo passing though Baltimore.

Total domestic general cargo movements have remained surprisingly constant during the 1953-1972 period, as shown in Figure 9-24. Marine transportation's biggest competitor for domestic traffic is the railroad. Each mode of transport has certain advantages over the other. Marine transport has an advantage in the movement of commodities which are generally shipped in high volumes such as bulk oil. Rail transport is more desirable when speed and flexibility are important. The marine mode's slower speed creates a serious competitive disadvantage for time-sensitive or high-value commodities as in the case of many general cargo items. Because of these factors, domestic movements of general cargo are not expected to increase to any significant extent in the future. The projections in Figure 9-24 assume that commerce will remain at about the 1965-1972 average of 2.1 million short tons.

TABLE 9-3
MAJOR GENERAL CARGO COMMODITIES
AND TYPE OF TRAFFIC, BALTIMORE HARBOR, 1972

Foreign	Tons (thousands)	Percent of Total
Bananas and Plantains (I)	383	8.5
Lumber (I)	380	8.4
Metal Products (I & II)	1,272	28.3
Standard Newsprint (I)	100	2.2
Miscellaneous Chemicals (I & E)	294	6.5
Cars and Other Transportation Equipment (I & E)	500	11.1
Machinery (I & E)	285	6.3
Other Miscellaneous	1,301	28.7
Total	4,515	100.0
Domestic		
Metal Products (S)	1,175	54.2
Miscellaneous Chemicals (S)	216	10.0
Agricultural, Food, and Marine Products (R & S)	174	8.0
Lumber (R)	86	4.0
Other Miscellaneous	514	23.8
Total	2,165	100.0

I = Imports E = Exports R = Receipts S = Shipments

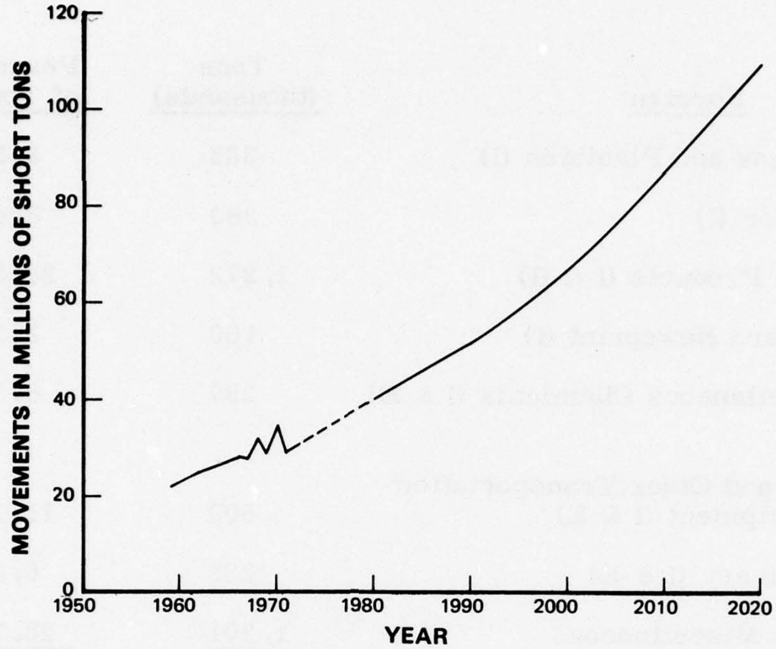

Figure 9-21: TOTAL EAST COAST GENERAL CARGO - FOREIGN MOVEMENTS

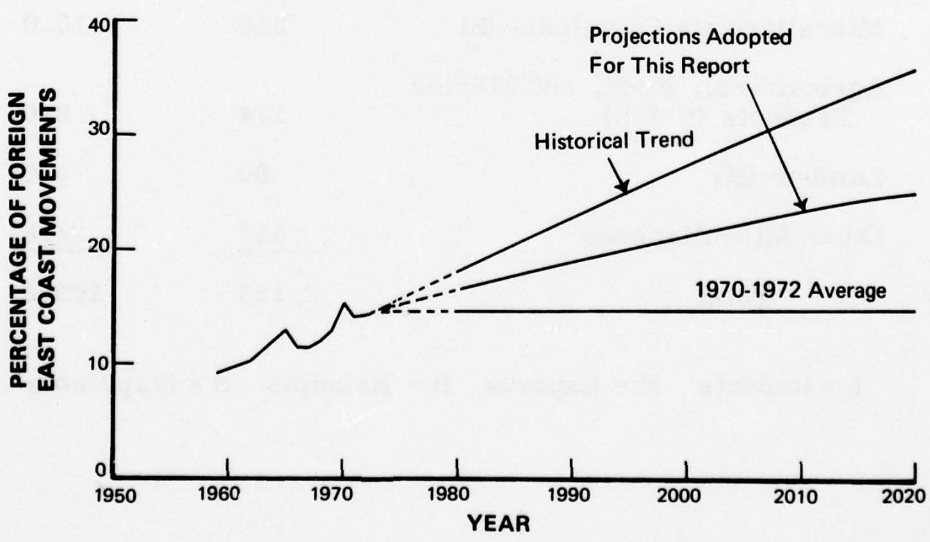

Figure 9-22: BALTIMORE HARBOR GENERAL CARGO - PERCENTAGE OF FOREIGN EAST COAST MOVEMENTS

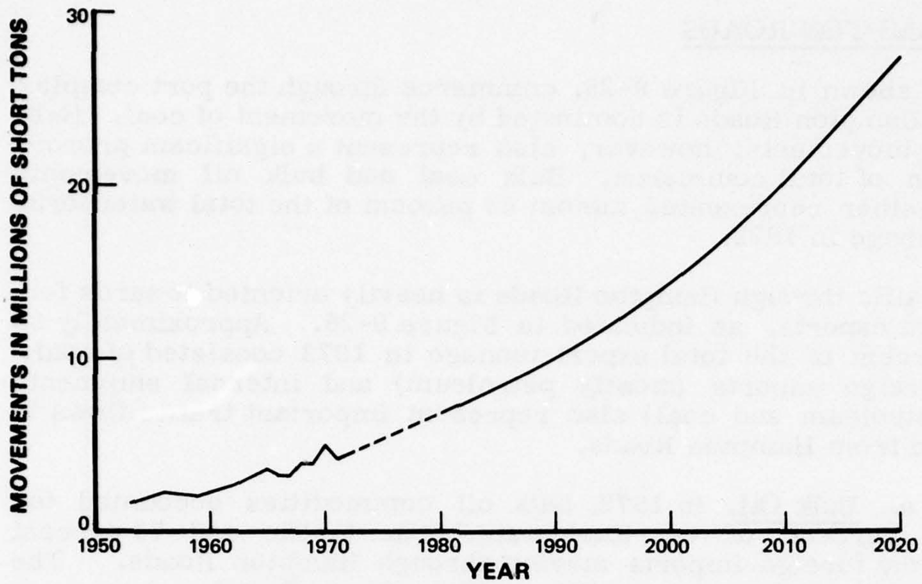

Figure 9-23: BALTIMORE HARBOR GENERAL CARGO - FOREIGN MOVEMENTS

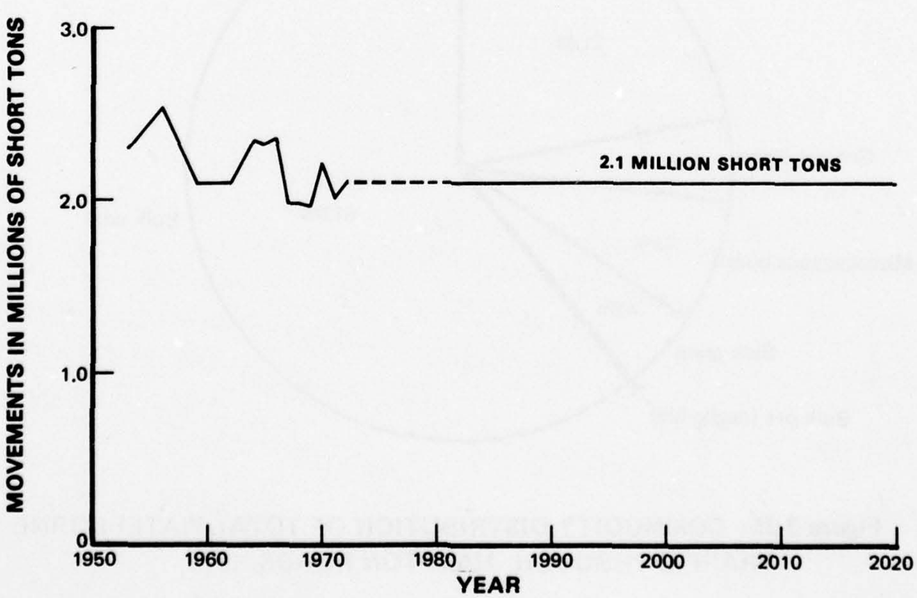

Figure 9-24: BALTIMORE HARBOR GENERAL CARGO - DOMESTIC MOVEMENTS

HAMPTON ROADS

As shown in Figure 9-25, commerce through the port complex of Hampton Roads is dominated by the movement of coal. Bulk oil movements, however, also represent a significant proportion of total commerce. Bulk coal and bulk oil movements together represented almost 83 percent of the total waterborne tonnage in 1972.

Traffic through Hampton Roads is heavily oriented towards foreign exports, as indicated in Figure 9-26. Approximately 88 percent of the total export tonnage in 1972 consisted of coal. Foreign imports (mostly petroleum) and internal shipments (petroleum and coal) also represent important traffic flows to and from Hampton Roads.

a. Bulk Oil. In 1972, bulk oil commodities accounted for 22 percent of the total waterborne traffic and 72 percent of the foreign imports moving through Hampton Roads. The most important commodities within the bulk oil group were residual fuel, gasoline, and distillate fuel. Approximately 71 percent of the bulk oil passing through the port complex is either foreign or domestic inbound.

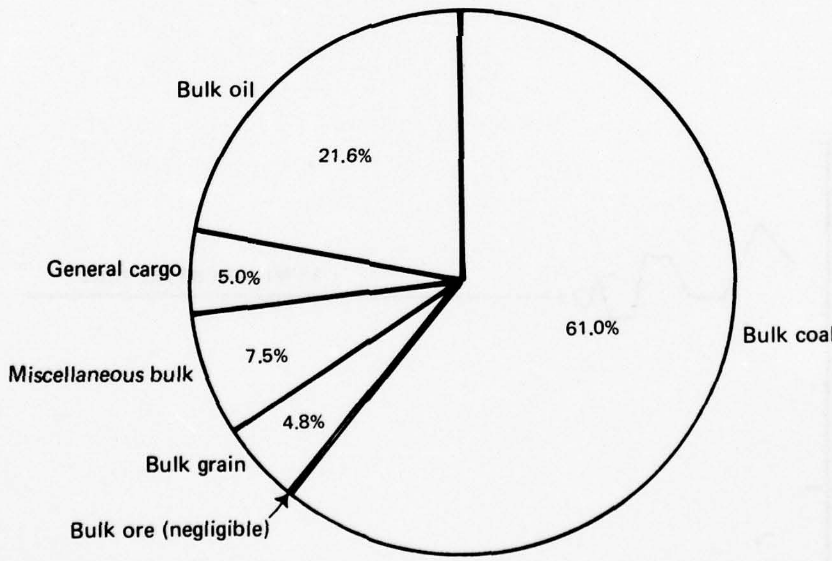

Figure 9-25: COMMODITY DISTRIBUTION OF TOTAL WATERBORNE TRAFFIC THROUGH HAMPTON ROADS, 1972

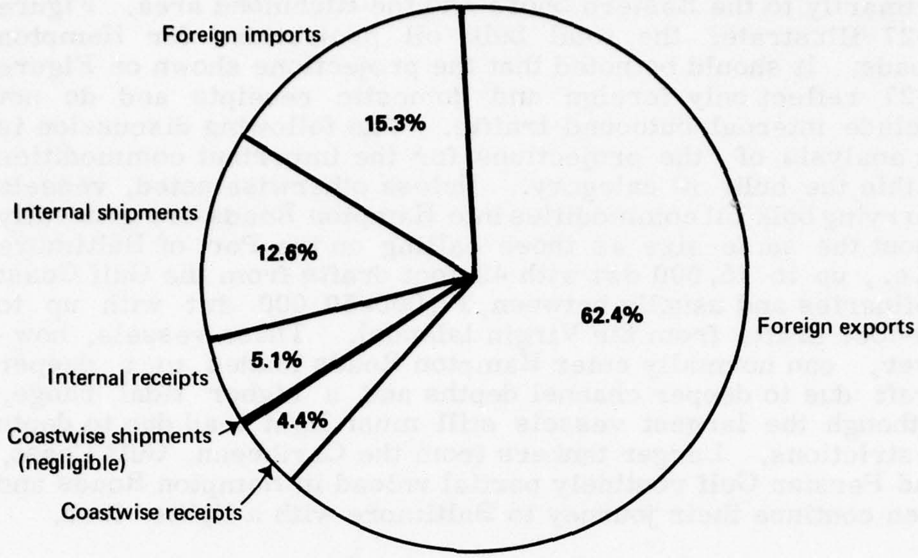

Figure 9-26 : DISTRIBUTION OF MAJOR TRAFFIC FLOWS THROUGH HAMPTON ROADS, 1972

As shown in Figure 9-27, total inbound petroleum traffic (i.e., waterborne plus pipeline) decreased significantly after 1964 in contrast to the fairly steady increase experienced in Baltimore. This was due to the fact that prior to the initiation of petroleum pipeline service to the Chesapeake Bay Region metropolitan areas in 1964, Hampton Roads served as a major distribution point for petroleum products for Bay area towns and cities as far north as Washington, D.C. Deep draft vessels would unload at tank farms in the Hampton Roads area from which petroleum products were barged to Richmond, Petersburg, Hopewell, Fredericksburg, and Washington, D.C. After 1964, large volumes of petroleum products were diverted to the pipelines. As a result, total inbound bulk oil traffic, as well as internal shipments of bulk oil, decreased significantly during the years following 1964. Most of the increase in internal shipments since 1968 has been due to an increase in demand for residual fuel for power plant use.

At the present time, the vast majority of the bulk oil shipped into Hampton Roads is consumed somewhere within the Norfolk-Portsmouth Economic Area although the specific distribution area depends on the commodity. There are still some internal shipments of gasoline and distillate fuel out of Hampton Roads,

primarily to the Eastern Shore and the Richmond area. Figure 9-27 illustrates the total bulk oil projections for Hampton Roads. It should be noted that the projections shown on Figure 9-27 reflect only foreign and domestic receipts and do not include internal-outbound traffic. The following discussion is an analysis of the projections for the important commodities within the bulk oil category. Unless otherwise noted, vessels carrying bulk oil commodities into Hampton Roads are generally about the same size as those calling on the Port of Baltimore (i.e., up to 75,000 dwt with 42-foot drafts from the Gulf Coast refineries and usually between 30,000-50,000 dwt with up to 39-foot drafts from the Virgin Islands). These vessels, however, can normally enter Hampton Roads loaded to a deeper draft due to deeper channel depths and a higher tidal range, although the largest vessels still must light load due to depth restrictions. Larger tankers from the Caribbean, Gulf Coast, and Persian Gulf routinely partial unload in Hampton Roads and then continue their journey to Baltimore with a lighter load.

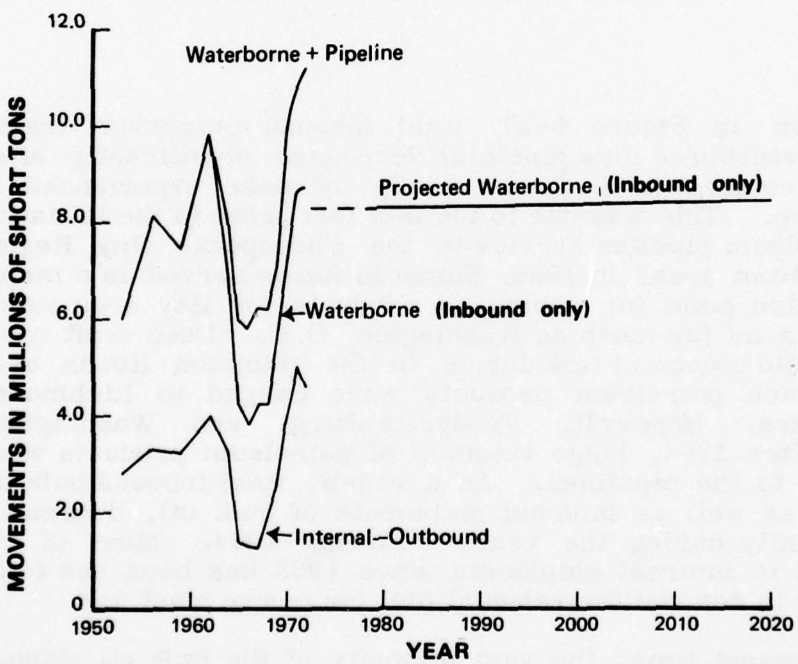

Figure 9-27: HAMPTON ROADS BULK OIL TRAFFIC - HISTORICAL AND PROJECTED

(1) Residual fuel. The largest users of residual fuel oil in the Norfolk-Portsmouth area are the public utility companies which accounted for approximately one-half of the total consumption in 1972. An additional 25 percent was used by industry and large commercial establishments for heating and processing purposes. Smaller amounts were used by the military and as bunker fuel. In 1972, slightly over 6.7 million short tons of residual fuel were transported into Hampton Roads by water (see Figure 9-28), 96 percent of which was carried over the ocean. Most of this originated in Venezuela or the Caribbean Islands (including the Virgin Islands). Additional tonnages were transported from the Delaware River and Gulf Coast refineries.

In order to project future levels of residual oil movements into Hampton Roads, it was necessary to estimate historical consumption of residual fuel, by use, for the Hampton Roads distribution area. (29) Power plant use of residual was negligible before 1968 when consumption increased sharply due to more stringent air quality regulations. The Virginia Electric and Power Company (VEPCO) is, by far, the largest user of residual fuel in the area. VEPCO's consumption of residual fuel is expected to decline in the future as nuclear power plants and more efficient oil and coal burning facilities come into operation. Residual fuel use by power plants is projected to decline by an average of approximately 6 percent annually during the 1972-2000 period, after which it is assumed to decline to zero by the year 2020. (30) Industrial and commercial use of residual fuel was related to total income in the Norfolk-Portsmouth Economic Area. Residual used for bunker fuel was projected by extending the 1963-1972 trend as the overall level of traffic in the Hampton Roads area is expected to continue to increase. As a result of one of the basic assumptions of the OBERS projections that the military force will remain constant at about the 1970 level, military use of residual was also assumed to remain at a constant level (before adjustment). The final projections are presented in Figure 9-28. The overall decline in the projections is based on the expected decline in power plant use.

(2) Gasoline. The major users of gasoline in the Hampton Roads distribution area are cars, trucks, and buses. The approximately three-quarters of a million short tons of gasoline shipped by water into the port complex accounted for about 33 percent of the total inbound shipments of 2.25 million short tons. About 75 percent of the waterborne receipts were oceangoing in 1972, mainly from the Gulf Coast refineries.

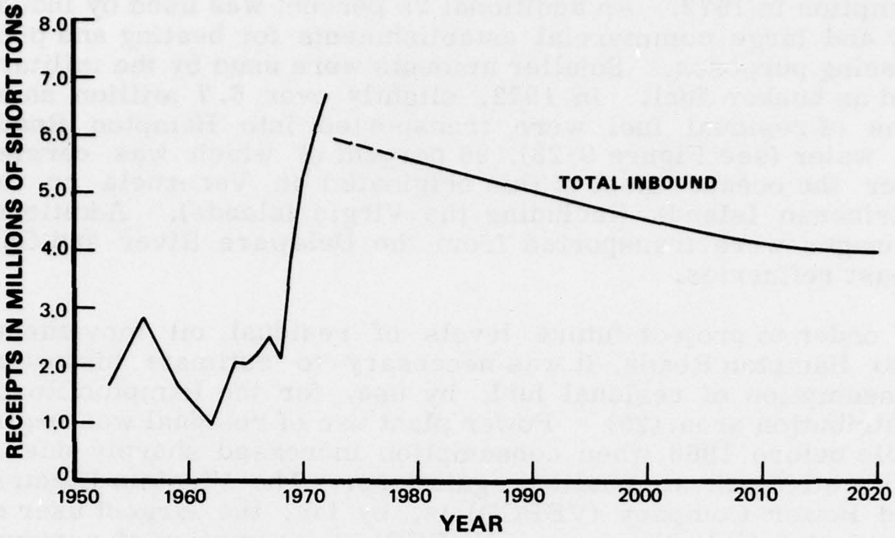

Figure 9-28: HAMPTON ROADS BULK OIL - RESIDUAL FUEL OIL

In order to project future movements of gasoline into Hampton Roads it was necessary to calculate "net inbound receipts" (i.e., total inbound minus total outbound) because of the effect on outbound shipments of the petroleum products pipeline (see Figure 9-29). Since most of the outbound shipments of gasoline from Hampton Roads are transported out of the Norfolk-Portsmouth Economic Area, mainly by barge to the Eastern Shore towns, net inbound receipts (including pipeline) represents the demand for gasoline within the Economic Area. Between 1953 and 1972, demand increased by slightly over 3 percent annually. These receipts were highly correlated with population and per capita income in the Area. Outbound shipments were assumed to remain constant at the 1970-1972 average of 370,000 short tons. Total inbound waterborne projections for gasoline (i.e., net inbound receipts plus total outbound) are presented in Figure 9-29. The projected rate of growth is approximately 2.75 percent annually over the 1972-2000 period.

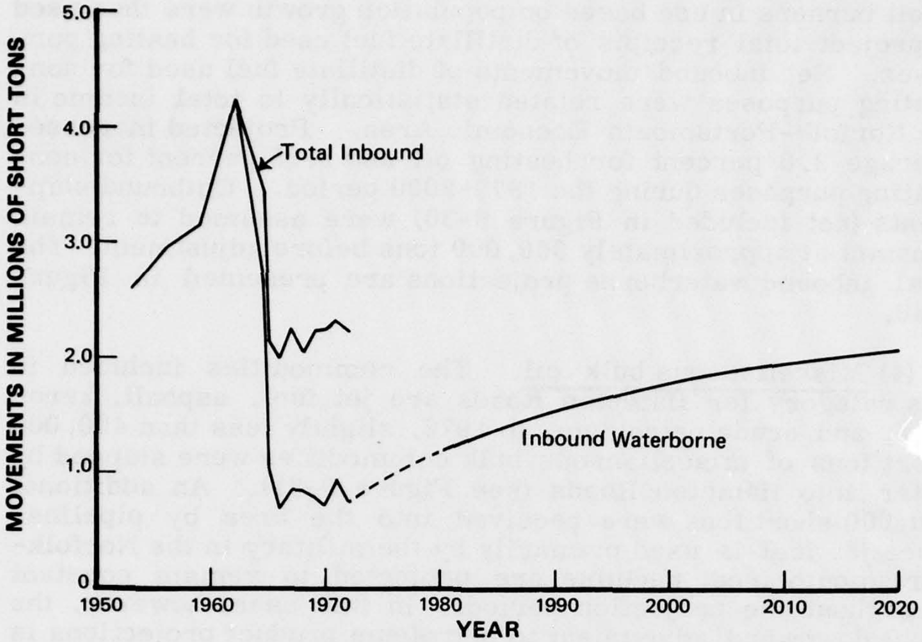

Figure 9-29: HAMPTON ROADS BULK OIL - GASOLINE

(3) Distillate fuel. Most of the distillate fuel used in the Norfolk-Portsmouth area is used for home and commercial heating. There are, however, other important uses of distillate-type fuels including its use in diesel-powered vehicles, peak load power plants, and industrial heating and processing. Inbound waterborne receipts of distillate fuel in 1972 totaled almost 650,000 short tons. This volume represented approximately 40 percent of the total distillate receipts including pipeline. About 90 percent of the waterborne receipts were ocean-going, either from the Gulf Coast refineries or the Caribbean area.

The projection methodology used for distillate fuel movements into Hampton Roads is similar to that used for Baltimore. Based on sales data for the Commonwealth of Virginia, estimates were made of the proportion of total inbound receipts used for heating and non-heating purposes. In addition, as in the case of the gasoline projections for Hampton Roads, net inbound receipts and total outbound shipments of distillate were projected separately. Net inbound distillate fuel for heating

purposes was related to the number of oil burners in use in the distribution area during the 1953-1972 period. Forecasts of oil burners in use based on population growth were then used to project total receipts of distillate fuel used for heating purposes. Net inbound movements of distillate fuel used for non-heating purposes were related statistically to total income in the Norfolk-Portsmouth Economic Area. Projected increases average 2.0 percent for heating oil and 2.25 percent for non-heating purposes during the 1972-2000 period. Outbound shipments (not included in Figure 9-30) were assumed to remain constant at approximately 550,000 tons before adjustment. The total inbound waterborne projections are presented in Figure 9-30.

(4) Miscellaneous bulk oil. The commodities included in this category for Hampton Roads are jet fuel, asphalt, kerosene, and crude petroleum. In 1972, slightly less than 400,000 short tons of miscellaneous bulk commodities were shipped by water into Hampton Roads (see Figure 9-31). An additional 320,000 short tons were received into the area by pipeline. Since jet fuel is used primarily by the military in the Norfolk-Portsmouth area, receipts are projected to remain constant throughout the projection period. In this case, however, the usual downward adjustment to petroleum product projections is not made because it was assumed that increases in civilian use would offset the decreases in military use due to the adjustment. Asphalt shipments have remained at a fairly constant level during the period of record. They are assumed to remain relatively constant in the future. Kerosene, used mainly for space heaters and cooking stoves, has not fared well in the Hampton Roads distribution area in its competition with bottled gas. Kerosene shipments are projected to decline at the rate indicated by the 1965-1972 time trend. Crude petroleum receipts are insignificant in Hampton Roads due to the present absence of any petroleum refineries in the area (see Sensitivity Analysis section). Total projections for miscellaneous bulk commodities are presented in Figure 9-31.

b. Bulk Coal. Hampton Roads is the most strategically located port in the United States with respect to the rich Appalachian coal fields. In 1972, 31.5 million short tons of coal were exported through the port complex. Hampton Roads annually accounts for roughly 60 percent of the total U.S. foreign exports (including rail shipments to Canada).

Almost all of the coal exports leaving Hampton Roads consist of bituminous coal for the production of coke for metallurgical purposes. Coal of different classes is usually blended at the coke oven in the importing country to achieve coke with optimum metallurgical properties. Certain classes of coal are

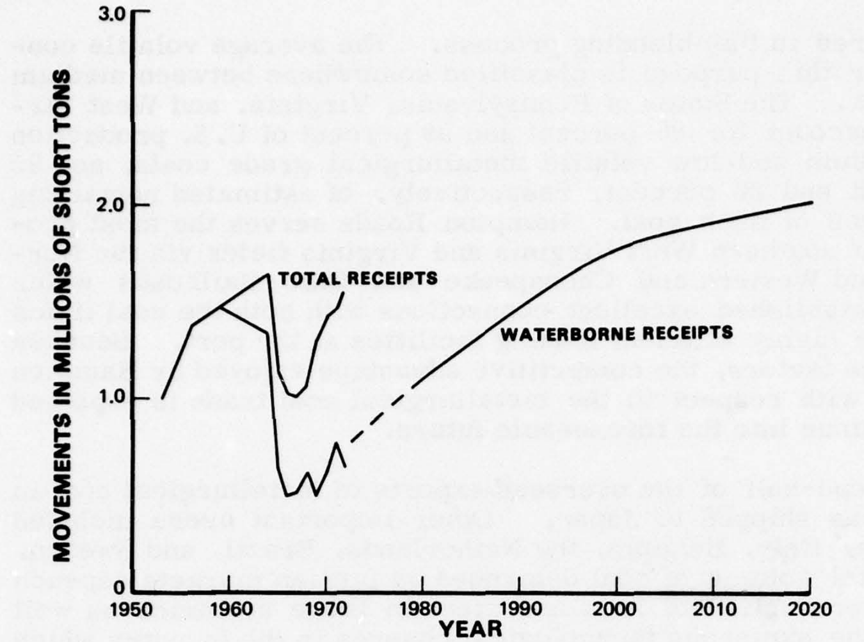

Figure 9-30: HAMPTON ROADS BULK OIL - DISTILLATE FUEL OIL

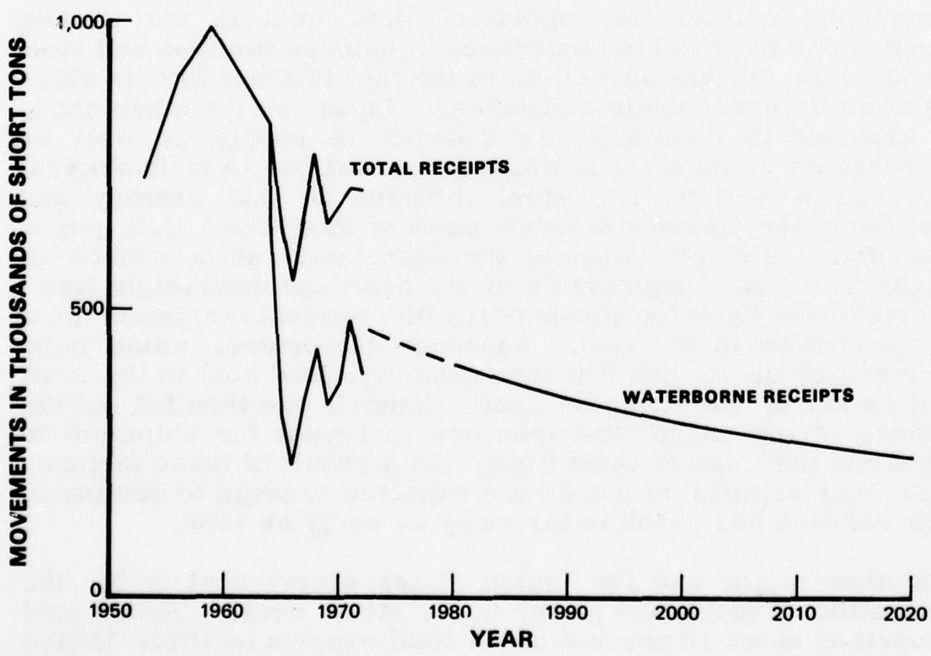

Figure 9-31: HAMPTON ROADS BULK OIL - MISCELLANEOUS PRODUCTS

preferred in this blending process. The average volatile content for this purpose is classified somewhere between medium and low. The States of Pennsylvania, Virginia, and West Virginia account for 96 percent and 99 percent of U.S. production of medium and low volatile metallurgical grade coals, and 95 percent and 88 percent, respectively, of estimated remaining reserves of such coal. Hampton Roads serves the most productive southern West Virginia and Virginia fields via the Norfolk and Western and Chesapeake and Ohio Railroads which have established excellent connections with both the coal fields and the highly efficient loading facilities at the port. Because of these factors, the competitive advantage enjoyed by Hampton Roads with respect to the metallurgical coal trade is expected to continue into the foreseeable future.

About one-half of the overseas exports of metallurgical coal in 1972 was shipped to Japan. Other important users included France, Italy, Belgium, the Netherlands, Brazil, and Sweden. The total volume of coal demanded by foreign markets depends on the production of iron and steel in those countries as well as on the numerous technological changes in the industry which have altered the coke/pig iron ratio. During the period between 1960 and 1967, the consumption of coal per ton of pig iron declined by 19 percent in Japan and 30 percent in the European Economic Community (EEC) countries. (32)

Despite these technological advances, Western Europe is expected to increase its imports of U.S. coal in the coming decades due to projected increases in demand for iron and steel products in Europe as well as to the fact that the EEC is closing down its uneconomic collieries. Japan, on the other hand, is expected to diversify its sources of supply as well as decrease its demand for metallurgical coal due to technological advances in the iron and steel industry in that country and because of the distance disadvantages of East Coast U.S. ports. The distance disadvantage of the East Coast as a source of supply to Japan is aggravated by the draft and deadweight limitations of the Hampton Roads ports (the present maximum depth of the channel is 45 feet). Japanese importers, using bulk carriers of up to 150,000 tons capacity, load coal to the draft limitations of the Hampton Roads channels and then fill out the balance of the cargo with iron ore in Brazil for shipment to Japan via the Cape of Good Hope. As a result of these factors, U.S. coal exports to Japan are expected to begin to decline in both relative and absolute terms by as early as 1980.

The other major use for United States export coal is for the generation of electrical power (i.e., steam coal). Steam coal comprised about 10 percent of the total exports in 1970. United States exports of steam coal declined substantially during the

1960's from an average of 8.4 million tons in 1961-62 to 4.7 million tons during 1969-70. In Western Europe, the destination of most of the steam coal exported by this country, increasing preference has been given to indigenous coal through import quotas, and direct subsidies. Indigenous resources of steam coal are much more common in Western Europe than metallurgical coal resources. In 1970, only West Germany continued to import any appreciable quantities of U.S. steam coal (about 90 percent of the total).

The average size vessel carrying coal out of Hampton Roads is in the 50-75,000 dwt range with 38 to 46-foot drafts. However, vessels of over 100,000 dwt are not uncommon. The largest ship to ever call on the port was a vessel of 169,430 dwt which loaded coal bound for Japan.

Robert R. Nathan Associates in the Deepwater Port Study predicted a significantly higher level of coal exports through Hampton Roads than has prevailed in the recent past. The latest data available at the time the Nathan report was published was 1970. Since 1970, the volume of shipments has dropped considerably from the high 1970 level as shown in Figure 9-32. The 1971-74 average tonnage was 32.5 million short tons as compared to 46.2 million in 1970. One explanation given for this decline is that increasing domestic demand for the low-sulfur coal mined in the area served by Hampton Roads has reduced the supply availble for export, as well as raised the price of export coal. Nathan's projection for 1980 is 55.4 million short tons including an estimated 3.2 million short tons of exported steam coal which is assumed to remain constant throughout the projection period.(33) In contrast, the Norfolk and Western Railroad, which handles roughly 70 percent of the export coal passing through the port, is predicting total exports of 42.8 million short tons in the year 1980.(34) The basic assumption made in this Study is that the level of shipments projected by Nathan will be attained, but not until the year 1990. For 1980, 42.8 million short tons as predicted by the Norfolk and Western Railroad is used. Since Nathan's projections were not prepared past the year 2000, it is assumed that the level of exports will remain at the 2000 level for the remainder of the projection period.

In addition to the huge quantities of coal exported to foreign countries each year from Hampton Roads, significant volumes of coal are also shipped from the port via domestic trade routes. Virtually all of this traffic, which totaled approximately 3.3 million short tons in 1972, consisted of internal barge shipments of coal to Baltimore and Delaware River destinations for metallurgical purposes.

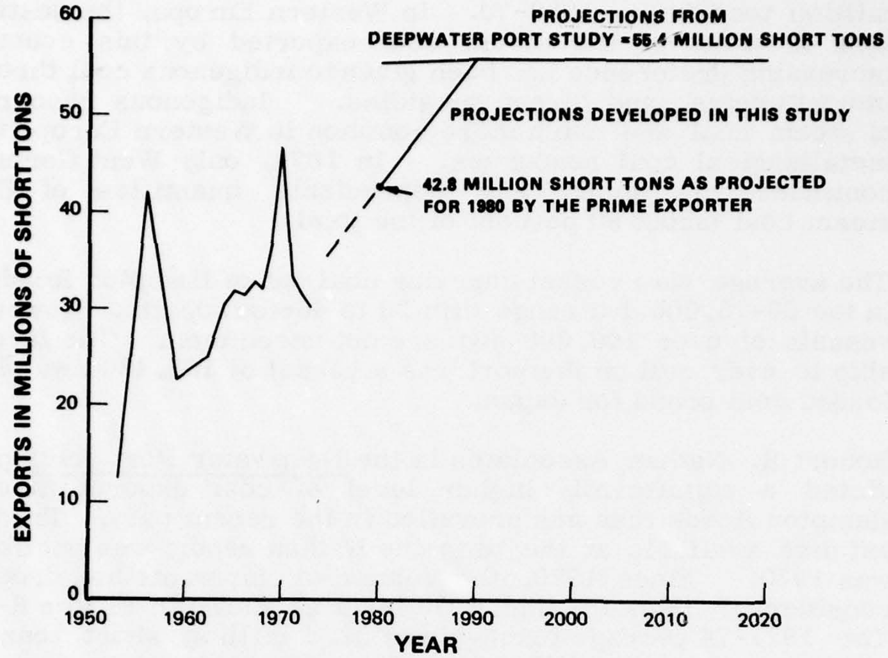

Figure 9-32: BULK COAL EXPORTS - HAMPTON ROADS

c. Bulk Grain. Bulk grain is the second largest export category passing through Hampton Roads. In 1972, approximately 2.6 million short tons of grains were exported from the port complex. Most of the grains were grown in the Midwestern and South Atlantic states and are generally shipped to Western and Eastern European countries. The major types of grains handled are corn, wheat, and soybeans and soybean meal. Due to the relatively small volumes of export grain handled at Hampton Roads, the vessels carrying these commodities are significantly smaller than those handling coal. The average vessel is in the 25-35,000 dwt range with 32 to 36-foot drafts, although ships in the 100,000 dwt class occasionally call on the port.

Except for a significant drop during the 1969-1971 period, grain exports through Hampton Roads have remained at a relatively constant level since 1960 (see Figure 9-33). Using the same methodology as explained in the Baltimore Harbor section on bulk grain, projections of grain exports from Hampton Roads were calculated and the projections are shown in Figure 9-33. The mix of grains in the future is expected to remain about the same as the present mix.

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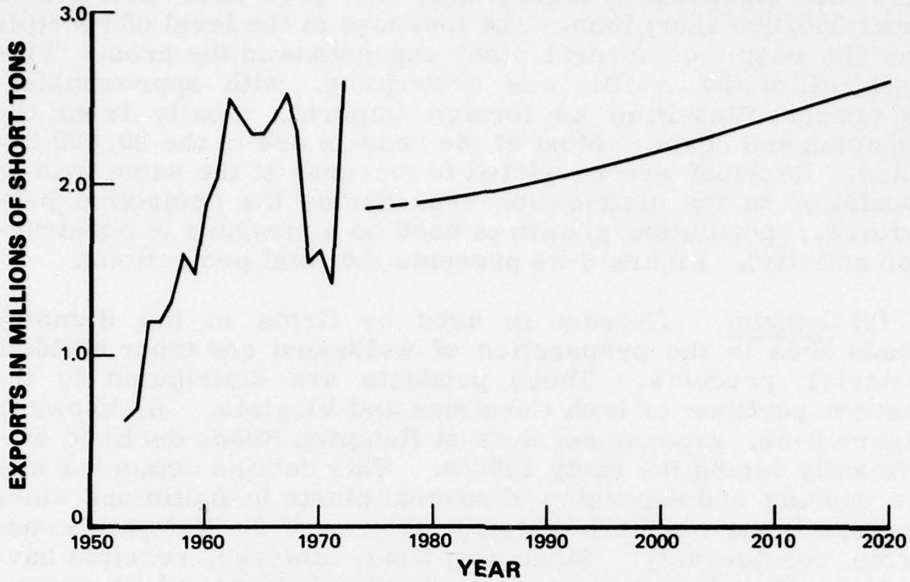


Figure 9-33: HAMPTON ROADS - BULK GRAIN FOREIGN EXPORTS

d. Miscellaneous Bulk. The most important commodities in this category are limestone, building cement, fertilizers, and sand, gravel, and crushed rock. In 1972, slightly under 4.0 million short tons of miscellaneous bulk commodities passed through the port complex of Hampton Roads. Approximately 45 percent of these shipments were classified as oceangoing with virtually all of the remainder listed as domestic barge movements. The commodities in this category are raw or partially processed materials shipped into Hampton Roads for further processing (most by factories in the port area or for distribution without further processing. The following sections discuss the important commodities within the miscellaneous bulk category.

(1) Building cement. Building cement is received in the raw form by several firms in the Hampton Roads area where it is processed and distributed to eastern Virginia and North Carolina for general construction purposes. In 1972, just over 600,000 short tons of building cement were shipped into Hampton Roads.

This was significantly higher than the 1966-1971 average of about 250,000 short tons. The increase in the level of receipts was the result of several plant expansions in the area. Virtually all of the traffic was oceangoing, with approximately 70 percent classified as foreign imports, mostly from the Bahamas and Spain. Most of the vessels are in the 20,000 dwt class. Receipts are projected to increase at the same rate as population in the distribution area during the projection period (i.e., population growth is used as a measure of construction activity). Figure 9-34 presents the final projections.

(2) Gypsum. Gypsum is used by firms in the Hampton Roads area in the preparation of wallboard and other building material products. These products are distributed to the eastern portions of both Carolinas and Virginia. As shown in Figure 9-35, gypsum receipts at Hampton Roads declined significantly during the early 1960's. This decline coincided with the opening and expansion of several plants in Baltimore which decreased the northern distribution area of the Hampton Roads firms considerably. Since that time, however, receipts have leveled-off and have even risen slightly during the last several years. The average vessel bringing gypsum into Hampton Roads is about 15,000 dwt with a draft of approximately mately 27 feet. Gypsum receipts into Hampton Roads in the future are projected to increase at the same rate as population in the distribution area.

(3) Sand, gravel, and crushed rock. Sand, gravel, and crushed rock are used in the Norfolk-Portsmouth Economic Area for general construction purposes. This commodity accounted for almost half of the total movements in the miscellaneous bulk category. All the traffic consists of barge shipments from the sand and gravel pits near Richmond on the James River to the Norfolk-Portsmouth area. Shipments are expected to increase at the same rate as population. The projections are shown in Figure 9-36.

(4) Residual miscellaneous bulk. The most important commodities in this category are chemical fertilizers and sulfur. In 1972, the 1.6 million short tons of commerce in this category were split about evenly between foreign and domestic movements with over three-quarters being oceanborne. During the last 5 years, however, traffic has declined somewhat despite increases in output in the area's chemical industry, the major user of the commodities in this category. Movements are projected to level off at the 1968-1972 average of 1.5 million short tons as shown on Figure 9-37.

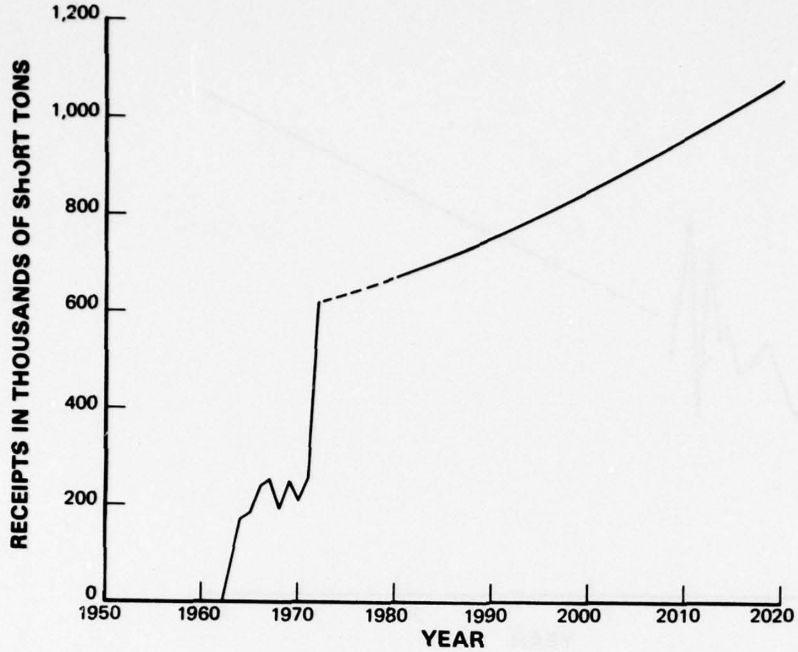


Figure 9-34: HAMPTON ROADS MISCELLANEOUS BULK - BUILDING CEMENT

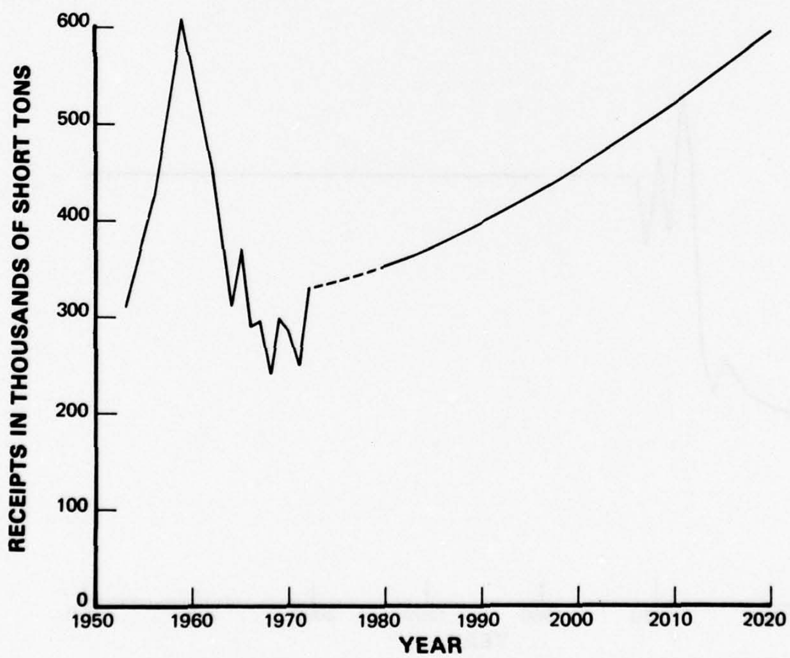


Figure 9-35: HAMPTON ROADS MISCELLANEOUS BULK - GYPSUM

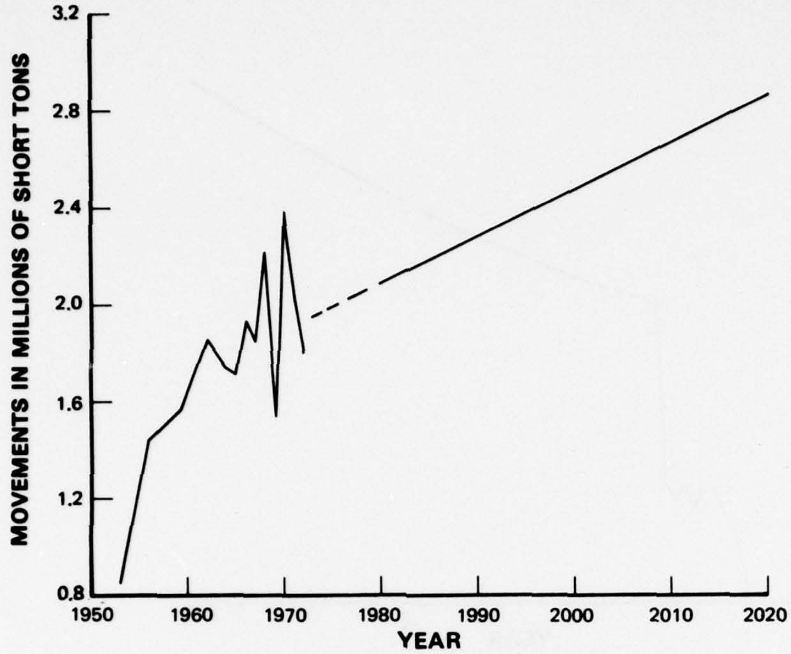


Figure 9-36: HAMPTON ROADS MISCELLANEOUS BULK - SAND, GRAVEL & CRUSHED ROCK

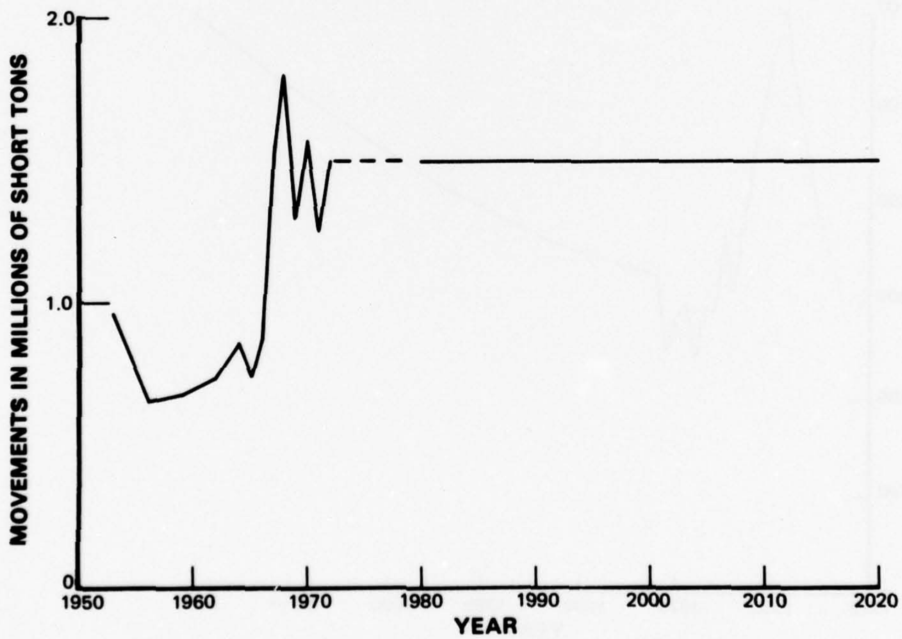


Figure 9-37: HAMPTON ROADS MISCELLANEOUS BULK - RESIDUAL

e. General Cargo. General cargo commodities accounted for 5 percent of the total commerce tonnage passing through the Hampton Roads complex. Slightly over 80 percent of the total general cargo traffic was listed as either foreign imports or foreign exports. About 60 percent of the foreign traffic was containerized in 1970. Table 9-4 below lists the major foreign cargo commodities passing through Hampton Roads.

TABLE 9-4
MAJOR FOREIGN GENERAL CARGO COMMODITIES AND TYPE OF TRAFFIC, HAMPTON ROADS, 1972

	Tons (Thousands)	Percent of Total
Lumber, Veneer, Plywood, and Other Wood Products (I & E)	246	10.6
Tobacco Leaf (I & E)	233	10.0
Machinery (I & E)	156	6.7
Motor Vehicles (I & E)	103	4.4
Basic Textile Products (I & E)	131	5.6
Metal Products (I & E)	268	11.5
Pulp and Paper Products (I & E)	118	5.1
Vegetable Oils, Margarine, Shortening (E)	88	3.8
Miscellaneous Chemicals (I & E)	88	3.8
Other Miscellaneous	897	38.5
TOTAL	2,328	100.0

I = Imports E = Exports

Hampton Roads serves as a water passageway for goods produced in, or bound for, much of the Southeast and Midwest east of Chicago. Most of the container ships currently calling on Hampton Roads are in the 15-20,000 dwt range with drafts between 28 to 32 feet. Hampton Roads' share of the total general cargo tonnage entering the East Coast has increased from 5.0 percent in 1959 to 8.4 percent in 1972. Using the methodology described in the beginning of this Chapter, it is assumed that the share of total foreign East Coast traffic handled by Hampton Roads will increase to 8.9 percent in 1980, 11.2 percent in 2000, and 13.3 percent in the year 2020, (see Figure 9-38).

CHESAPEAKE AND DELAWARE CANAL

The Chesapeake and Delaware Canal (C & D Canal) was first proposed over 300 years ago by a Dutch envoy, Augustine Herman, who was involved in a project to survey the Eastern Shore. It was not until 1804, however, that work actually began, and 1829 when the Canal, 13 miles long, 66 feet wide, and then only 10 feet deep, opened for business. The Canal originally had four locks with attendant pumphouses. One of the pumphouses remains today at Chesapeake City as a National Historic Landmark. The U.S. Government purchased the Canal in 1919 and widened it to 90-feet with a 12-foot depth in 1921. In 1935, it was widened again, this time to 250 feet and dredged to a depth of 27 feet. In 1954, Congress authorized a $100 million program to widen the channel to 450 feet and deepen it to 35 feet, and also replace several bridges along the waterway. The actual widening and deepening of the Canal did not get underway until 1962. A two-mile long "plug" was left in at the 27-foot level until the environmental effects of deepening the Canal could be determined. Having found that the environmental effects of deepening the Canal are minimal, dredging was recently completed on the project. Before the full benefits of the deeper Canal can be realized, however, maintenance dredging must be undertaken in the approach channel to the C & D Canal north of Baltimore Harbor where serious silting has occurred.

Commerce through the C & D Canal is dominated by the movement of bulk oil and general cargo, as shown in Figure 9-39. These two groups combine for approximately 88 percent of the total traffic.

Slightly over one-third (37 percent) of the movements in 1972 were foreign in origin or destination. Virtually all of this foreign traffic consisted of movements of general cargo. In 1972, approximately 58 percent of the vessels engaged in foreign traffic destined for or leaving from Baltimore traveled

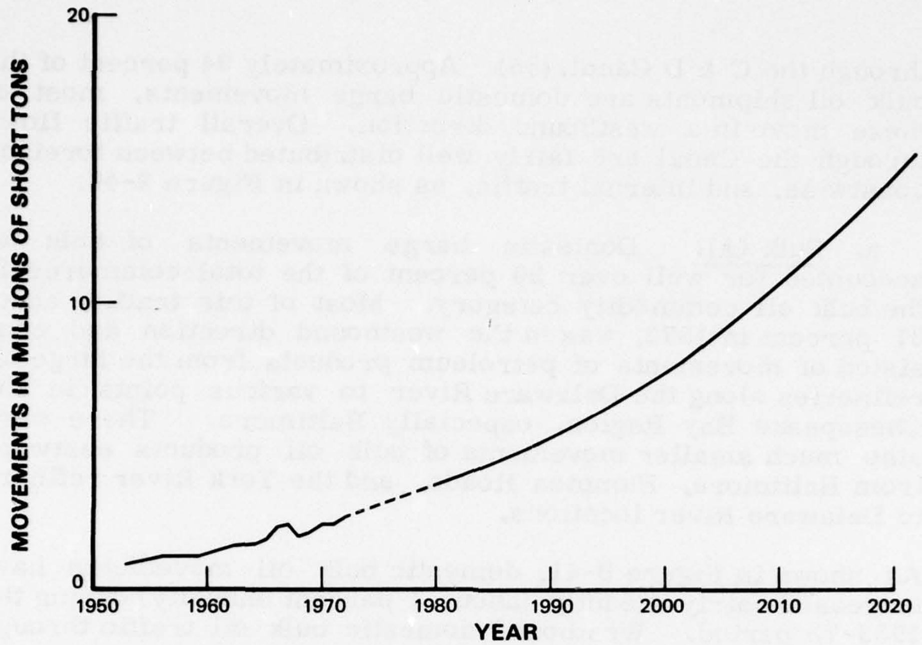


Figure 9-38: HAMPTON ROADS HARBOR GENERAL CARGO - TOTAL FOREIGN MOVEMENTS

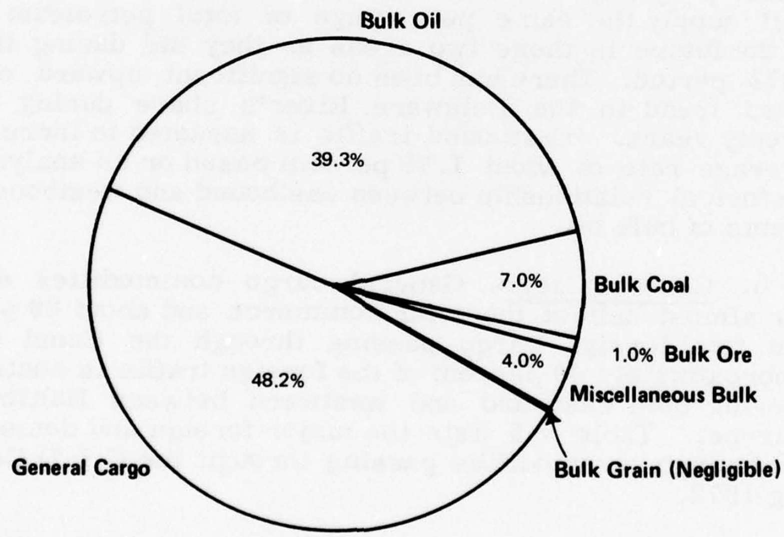


Figure 9-39: COMMODITY DISTRIBUTION OF WATERBORNE TRAFFIC THROUGH THE CHESAPEAKE AND DELAWARE CANAL, 1972

through the C & D Canal. (35) Approximately 94 percent of the bulk oil shipments are domestic barge movements, most of these move in a westbound direction. Overall traffic flows through the Canal are fairly well distributed between foreign, coastwise, and internal traffic, as shown in Figure 9-40.

a. Bulk Oil. Domestic barge movements of bulk oil accounted for well over 90 percent of the total commerce in the bulk oil commodity category. Most of this traffic, about 81 percent in 1972, was in the westbound direction and consisted of movements of petroleum products from the large oil refineries along the Delaware River to various points in the Chesapeake Bay Region, especially Baltimore. There were also much smaller movements of bulk oil products eastward from Baltimore, Hampton Roads, and the York River refinery to Delaware River locations.

As shown in Figure 9-41, domestic bulk oil movements have increased fairly steadily (about 3 percent annually) during the 1953-72 period. Westbound domestic bulk oil traffic through the C & D Canal is projected to increase at the average rate of about 1.8 percent during the 1970-2020 period. This percentage was derived by averaging the increase in demand for all petroleum products in Baltimore and Hampton Roads. These projections assume that the Delaware River refineries will supply the same percentage of total petroleum demand in the future in these two areas as they did during the 1970-1972 period. There has been no significant upward or downward trend in the Delaware River's share during the past twenty years. Eastbound traffic is assumed to increase at an average rate of about 1.75 percent based on an analysis of the historical relationship between eastbound and westbound movements of bulk oil.

b. General Cargo. General cargo commodities accounted for almost half of the total commerce and about 89 percent of the total foreign cargo passing through the Canal in 1972. Approximately 40 percent of the foreign traffic is containerized moving both eastward and westward between Baltimore and Europe. Table 9-5 lists the major foreign and domestic general cargo commodities passing through the C & D Canal during 1972.

For projection purposes, foreign and domestic movements were treated separately. During the past ten years, foreign commerce through the Canal has shown no significant upward or downward trend despite the fact that Baltimore Harbor has experienced a strong upward trend in this type of traffic during the same time period (see Figure 9-42). There are several reasons for this situation. First, many of the larger vessels

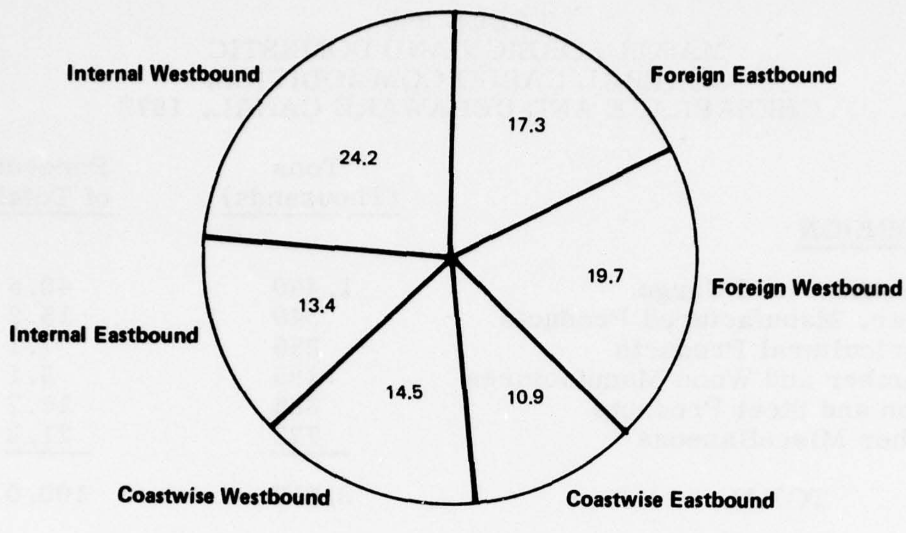


Figure 9-40: DISTRIBUTION OF MAJOR TRAFFIC FLOWS THROUGH THE CHESAPEAKE AND DELAWARE CANAL, 1972

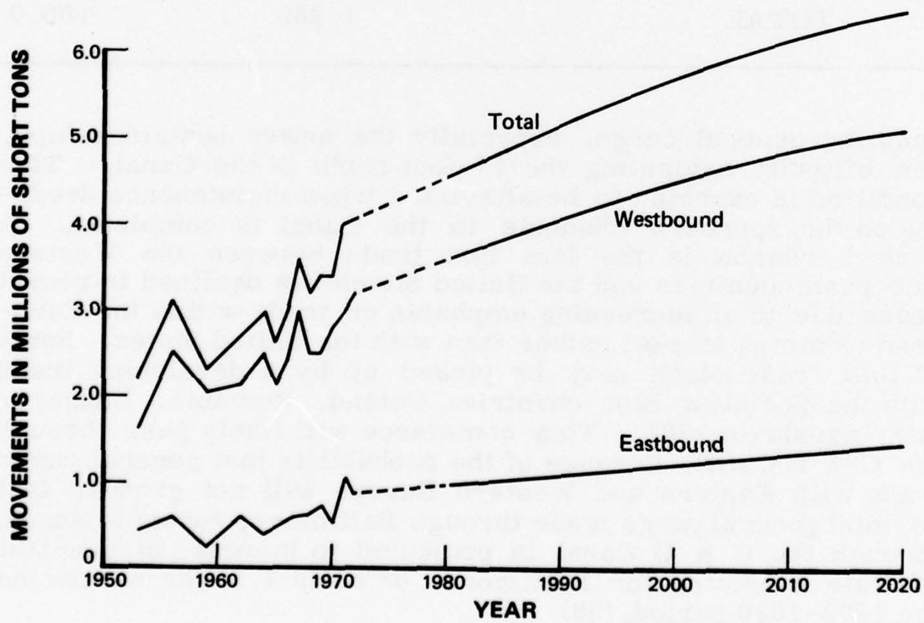


Figure 9-41: CHESAPEAKE AND DELAWARE CANAL BULK OIL - DOMESTIC TRAFFIC

TABLE 9-5
MAJOR FOREIGN AND DOMESTIC
GENERAL CARGO COMMODITIES,
CHESAPEAKE AND DELAWARE CANAL, 1972

	Tons (Thousands)	Percent of Total
FOREIGN		
Containerized Cargo	1,469	40.6
Misc. Manufactured Products	549	15.2
Agricultural Products	256	7.1
Lumber and Wood Manufactures	185	5.1
Iron and Steel Products	386	10.7
Other Miscellaneous	772	21.3
TOTAL	3,617	100.0
DOMESTIC		
Misc. Chemicals	602	35.7
Lumber and Wood Manufactures	116	6.9
Pulp, Paper, and Paper Products	271	16.1
Misc. Manufactured Products	215	12.8
Other Miscellaneous	465	28.5
TOTAL	1,669	100.0

handling general cargo, especially the newer containerships, had difficulty navigating the 27-foot depth of the Canal. This condition is expected to be alleviated when maintenance dredging on the approach channels to the Canal is completed. A second reason is the fact that trade between the Western European countries and the United States has declined in recent years due to an increasing emphasis on trade within the European Common Market rather than with the United States. Some of this trade slack may be picked up by a developing trade with the Socialist Bloc countries Poland, Rumania, Hungary, and Yugoslavia. (36) This commerce will likely pass through the C & D Canal. Because of the probability that general cargo trade with Eastern and Western Europe will not grow as fast as total general cargo trade through Baltimore, foreign tonnage through the C & D Canal is projected to increase at one-half the rate predicted for Baltimore, or about 1.9 percent during the 1972-2020 period. (36)

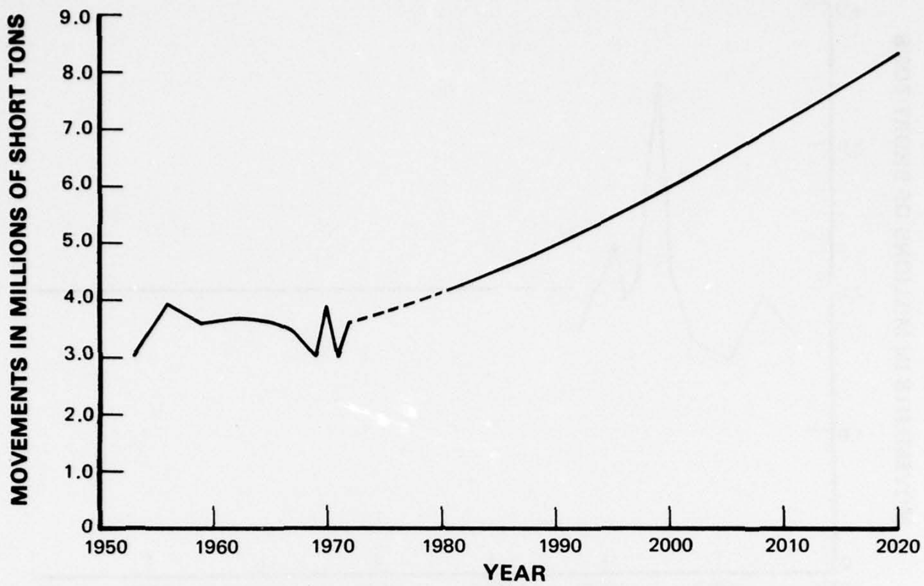


Figure 9-42: CHESAPEAKE AND DELAWARE CANAL GENERAL CARGO - FOREIGN

Domestic movements have fluctuated to a much greater degree than foreign (see Figure 9-43). Over the long term, however, there has been no significant upward or downward trend. Most of this traffic is commerce from Delaware River locations to points in Chesapeake Bay and the South Atlantic coast. For reasons similar to those given in the section on Baltimore's domestic general cargo projections, domestic general cargo movements are assumed to remain constant at the 1967-1972 average of 2.0 million short tons.

c. Residual Cargo. In addition to the relatively large volumes of bulk oil and general cargo traffic, there are significantly smaller quantities of bulk coal, bulk ore, bulk grain, and miscellaneous bulk passing through the C & D Canal. In 1972, these commodities totaled slightly less than 1.4 million short tons, or about 13 percent of the total commerce. Virtually all of the traffic consisted of domestic barge movements.

As shown in Figure 9-44, movements of goods in this commodity group have remained fairly constant since 1965 after fluctuating somewhat during earlier years. Changes in the quantity of coal moving through the Canal have accounted for most of the

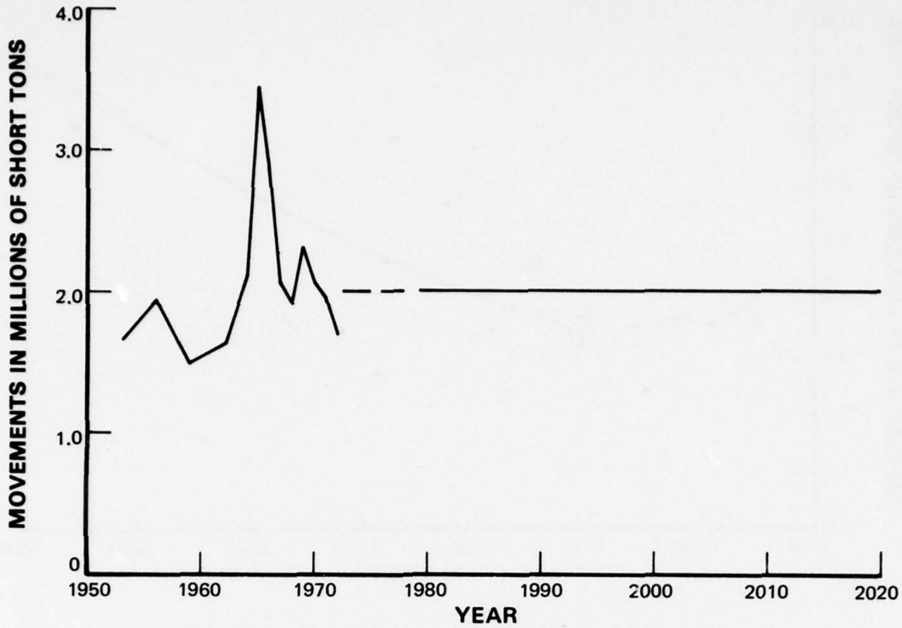


Figure 9-43: CHESAPEAKE AND DELAWARE CANAL - TOTAL DOMESTIC GENERAL CARGO

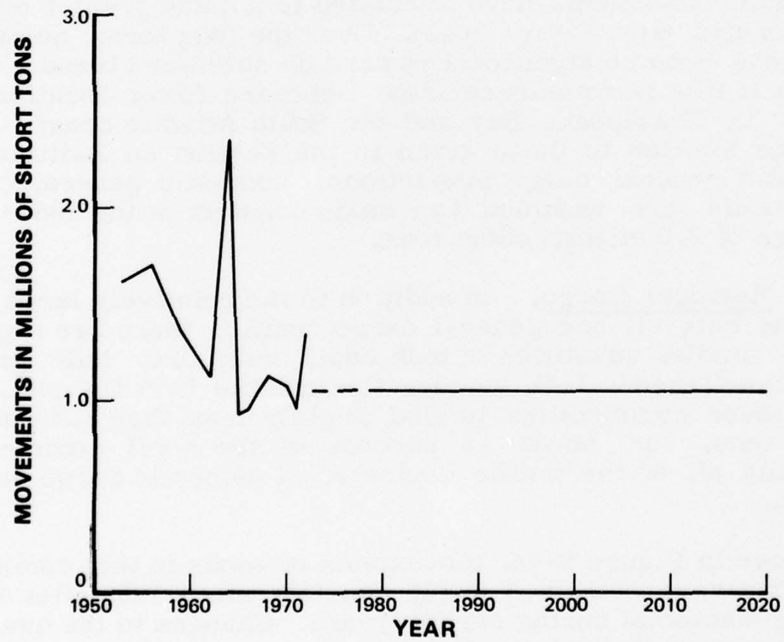


Figure 9-44: CHESAPEAKE AND DELAWARE CANAL - RESIDUAL CARGO (BULK COAL, ORE, GRAIN, AND MISCELLANEOUS BULK)

fluctuations in total movements during the last 10 years. The coal, which accounted for about half of the total tonnage in this category in 1972, is used for metallurgical purposes and for the generation of steam in Northeastern power plants. Traffic in this category is assumed to remain constant during the projection period at the 1965-1972 average of about 1.1 million short tons. However, the potential exists for a substantial increase in eastbound coal traffic depending on when and to what extent the Northeastern power plants switch to coal.

MINOR HARBORS AND WATERWAYS

There are well over one-hundred commercial harbors and waterways dotting the Chesapeake Bay and its tributaries. The vast majority of these handle only one or two commodities in relatively small volumes such as seafood or petroleum products. Others, such as Hopewell, Richmond, and Piney Point can be termed "minor" only in relation to the major international ports of Baltimore and Hampton Roads. For the purposes of this analysis, we considered for detailed study only those waterways with more than 200,000 short tons of commerce in 1970, as shown in the following list:

1. James River, Virginia
2. Potomac River, Maryland and Virginia
3. York River, Virginia
4. Wicomico River, Maryland
5. Nanticoke River, Maryland
6. Rappahannock River, Virginia
7. Choptank River (including the Tred Avon River), Maryland

In terms of tonnage, movements of bulk oil dominate the traffic on these waterways. In 1972, for example, approximately 70 percent of the total traffic consisted of petroleum and petroleum products. An additional 20 percent consisted of commodities in the miscellaneous bulk category such as sand and gravel, chemicals, and fertilizers.

1. <u>James River</u>. During the 1953-1972 period, total waterborne movements on the James River increased at a rate of about 2.5 percent annually despite a significant drop in bulk

oil movements during the middle 1960's. In 1972, there were 6.6 million short tons of commerce on the James River. Major flows of traffic consisted of internal barge movements of sand and gravel between the processing plants just below Richmond to the Hampton Roads and Richmond areas; and bulk oil barge traffic from Hampton Roads, Baltimore, and the Delaware River to Richmond, Hopewell, and the Chesterfield power plant (owned by VEPCO) downstream from Richmond. These two traffic flows accounted for 84 percent of the total waterborne movements on the James. In addition, there was some ocean-going commerce passing through the James consisting primarily of foreign exports of fertilizers and coastwise receipts of liquid sulfur to and from Hopewell, as well as foreign imports of tobacco leaf and imports and exports of other general cargo commodities to Richmond. These commodity movements accounted for almost one-half million short tons of commerce in 1972, or about 7 percent of the total tonnage. The ocean-going cargo vessels calling at James River ports average about 5,000 dwt with about 22-foot drafts, although there are some vessels up to 12,000 dwt with loaded drafts of 30 feet. Most of the dry cargo ships and tankers handling fertilizers and liquid sulfur through Hopewell are in the 20,000 dwt class with loaded drafts of over 30 feet. Since the main channel to the Richmond-Hopewell area is only 25 feet deep, the larger vessels are not able to load to capacity.

As shown in Figure 9-45, waterborne bulk oil movements on the James River exhibited the usual dip during the middle 1960's due to the opening of the petroleum pipelines. Both the Colonial and the Plantation pipeline companies serve the Richmond area. The distribution area for petroleum products shipped into Richmond includes most of the Richmond Economic Area. When pipeline and waterborne receipts are added, a steady increase in the demand for petroleum products in the Richmond area becomes evident. This increase averaged about 5.5 percent annually during the 1953-1972 period. Much of the increase since 1968 was due to the conversion of VEPCO's Chesterfield Power Plant from coal to residual fuel oil. The residual is barged to the plant after being unloaded from large tankers in Hampton Roads. In 1972, the Chesterfield plant used approximately 1.7 million short tons of residual fuel.

Projections of the demand for petroleum products in the Richmond Economic Area were prepared separately for both general use (e.g., industrial, transportation, heating) and power plant use. Estimates were made of general historical use. These estimates were correlated with total income in the economic area by regression analysis and projected to 2020. Projections of power plant use were supplied by VEPCO officials. Power plant use is expected to decline substantially by 1980

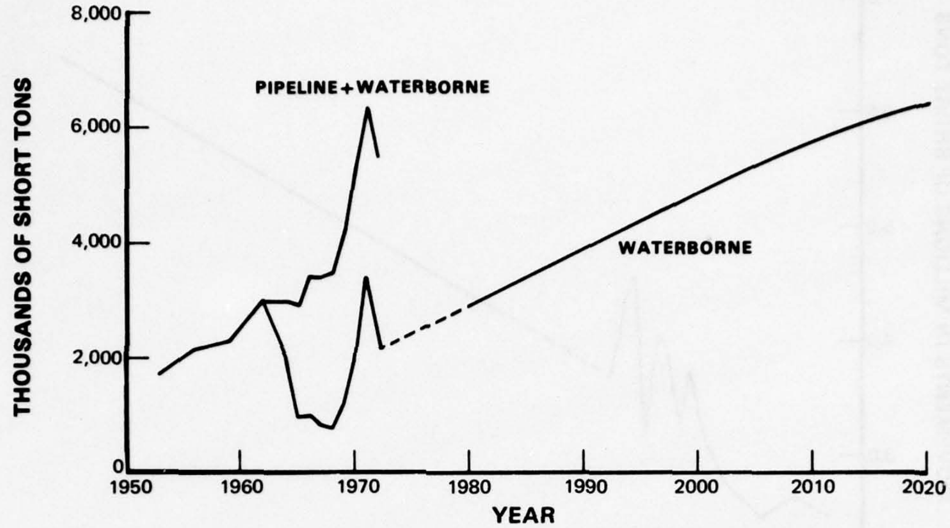


Figure 9-45: JAMES RIVER BULK OIL INTERNAL MOVEMENTS

to about 40 percent of the present consumption. After 1980, use gradually declines to zero by the year 2020. See Figure 9-45 for the projections of total bulk oil movements.

Over 90 percent of the remainder of the internal traffic in 1972 consisted of sand and gravel movements. Sand and gravel are used by the construction industry in the Norfolk-Portsmouth and Richmond Economic areas. Traffic is assumed to increase at the same rate as population in these areas (see Figure 9-46).

Oceangoing traffic has shown no statistically significant upward or downward trend over the 1953-1972 period. During the late 1960's, however, a jump upward of approximately 200,000 short tons occurred. This was mainly a result of an increase in the level of fertilizer exports from Hopewell. These fertilizer exports are expected to remain constant at about the existing level in the future. Projections of oceangoing commerce through the James River are shown in Figure 9-47. It was assumed that traffic will remain constant at the 1970-1972 average of 740,000 short tons.

2. Potomac River. In 1972, there was a total of slightly less than eight million short tons of commerce transported on the Potomac River. The Potomac, once envisioned as the major East Coast outlet for the produce of the Ohio Valley,

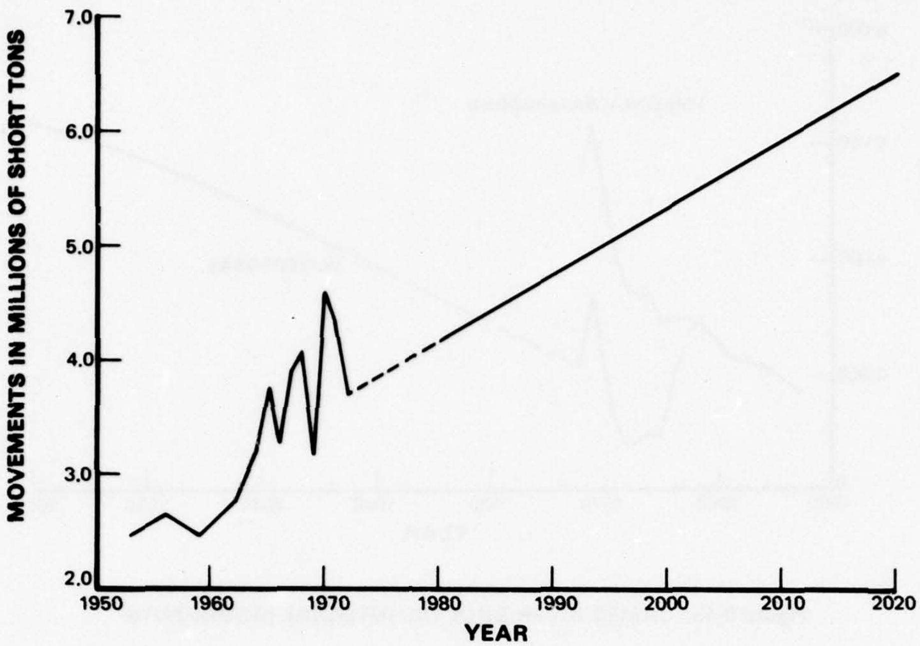


Figure 9-46: JAMES RIVER - INTERNAL TRAFFIC (EXCLUDING BULK OIL)

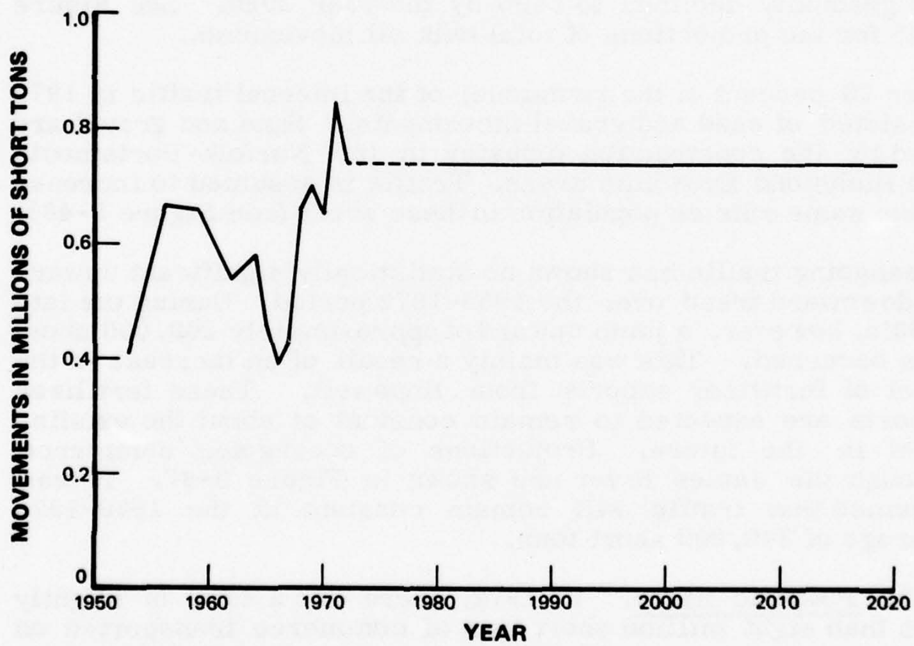


Figure 9-47: JAMES RIVER OCEAN-GOING TRAFFIC (FOREIGN+COASTWISE)

now imports many times more than it exports. Traffic on the Potomac is dominated by the movement of bulk oil into the river to help satisfy the Washington Metropolitan Area's tremendous demand for energy. This type of traffic accounted for approximately 87 percent of the total commerce on the Potomac in 1972. Most of the remaining traffic consisted of internal barge movements of sand and gravel to the Washington area from points along the Potomac River and foreign imports of newsprint into Alexandria, Virginia.

Bulk oil commodities destined for Washington are handled by the Stewart Petroleum Company's facility at Piney Point, Maryland, approximately 13 miles upstream from the confluence of the Potomac with Chesapeake Bay. Large oceangoing tankers, most in the 25-55,000 dwt size range with between 35 and 38-foot drafts, as well as barges from nearby domestic sources, carry petroleum products into Piney Point where they are unloaded and redistributed by pipeline and barge to the Washington, D.C. and Southern Maryland areas. Smaller amounts are shipped to other points around Chesapeake Bay and the Delaware River. Approximately 85 percent of the receipts at Piney Point were oceangoing.

The existing facilities at Piney Point include petroleum pipelines running from the Stewart facility to the Potomac Electric and Power Company (PEPCO) generating stations at Morgantown on the Potomac and Chalk Point on the Patuxent. In addition, Stewart also owns a pipeline between Piney Point and Andrews Air Force Base which is used primarily for the transport of jet fuel.

As shown in Figure 9-48, the initiation of the petroleum pipeline service from the Gulf Coast to the Washington area in 1964 caused a relatively moderate drop in the level of bulk oil traffic through Piney Point. The decline was moderated somewhat by an increase in demand for residual fuel by government and industry in the Washington area. There has been a substantial change since 1964 in the mix of petroleum commodities transported on the Potomac. Before 1964, the facility handled a much larger proportion of the "clean" products and a significantly smaller proportion of residual fuel. For example, in 1963, 42 percent of the oceangoing receipts at Piney Point were either gasoline or distillate fuel, in 1972 the proportion was 6 percent. Of the approximately 3.6 million short tons of commerce received at Piney Point in 1972, 81 percent were residual fuel for use by power plants, industry, and the government.

A major uncertainty concerning the use of residual fuel by the PEPCO Morgantown plant makes any effort to project bulk oil

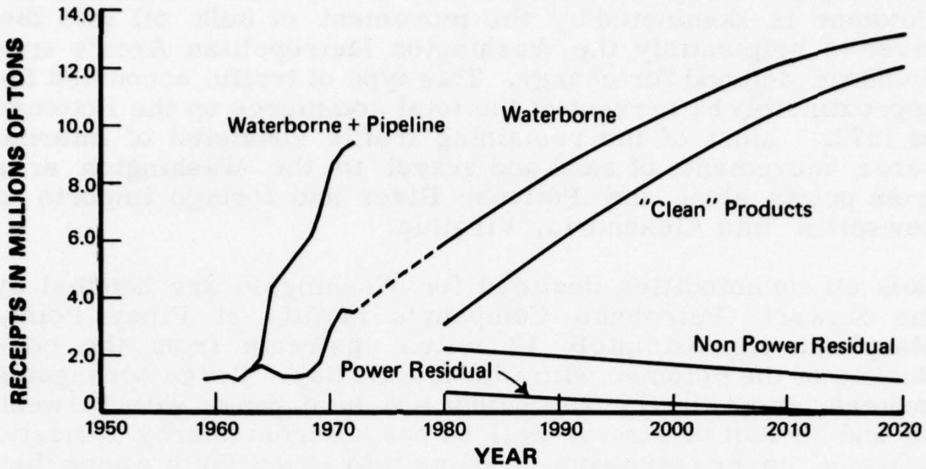


Figure 9-48: POTOMAC RIVER AT PINEY POINT - TOTAL RECEIPTS, HISTORICAL & PROJECTED

movements on the Potomac River extremely difficult. The uncertainty involves the Federal Energy Administration's (FEA) announced intentions in the Federal Register, May 16, 1975, to order the Morgantown plant to convert from oil to coal as a primary fuel despite the fact that PEPCO has a 20-year contract with Stewart to supply annually approximately 8,000,000 barrels (about 1.2 million short tons) of residual starting in 1975.(37) At this writing, the final outcome has not been resolved. Stewart also has other contractual obligations to supply approximately 2.4 million short tons of residual to public utilities, industries, and government over various time periods. In the projections presented in Figure 9-48, it is assumed that the Morgantown plant will convert to coal. In addition, it was assumed that any future decrease in consumption of residual by PEPCO's other plants on the Potomac will be compensated by increases in government and industrial use. As a result, movements of residual fuel into Piney Point are expected to remain constant at approximately 2.4 million short tons (before adjustment). VEPCO's Possum Point power plant, near Dumfries, Virginia, is the only generating plant on the Potomac not owned by PEPCO and also the only major petroleum products user on the River which has fuel sent directly to its plant, bypassing the Piney Point facility. Projections of residual use by the Possum Point plant were supplied by VEPCO. It is assumed that all inbound residual will be oceangoing except for the internal barge shipments destined for Possum

Point. Despite the relatively low level of waterborne movements of petroleum products other than residual fuel into the Potomac River in recent years (about 460,000 short tons in 1972) this type of traffic is expected to increase substantially in the future due to the expected higher than average increases in population and income in the Washington area and to our basic assumption that the petroleum pipelines are at or near capacity and that all additional increases in demand will be satisfied by waterborne movements. The projections for clean products presented in Figure 9-48 were prepared by correlating historical inbound with total income in the Washington, D.C. SMSA. It should be pointed out that prior to 1968 a large portion of Washington's petroleum supply was shipped from Baltimore by trucks. It is possible that a portion of the projected increase in demand will be satisfied by truck shipments in the future.

Predictions of outbound internal barge shipments of bulk oil from Piney Point to the Washington area and other points are illustrated in Figure 9-49. These were derived by subtracting projected Stewart pipeline shipments to the PEPCO power plants and Andrews Air Force Base from the projected total inbound bulk oil receipts at Piney Point.

Waterborne traffic other than bulk oil totaled almost 1.0 short tons in 1972. As mentioned above, this commerce consisted almost entirely of sand and gravel and newsprint. As shown in Figure 9-49, movements of these commodities have shown a steady decrease during the period of record. This is due almost entirely to a sharp drop in sand and gravel movements during the period because of regulations banning the dredging of sand and gravel from the Potomac for environmental reasons. Traffic other than bulk oil on the River is expected to level-off at about 500,000 short tons and remain constant throughout the projection period. The figure of 500,000 short tons includes approximately 200,000 short tons of newsprint, which is also expected to remain constant to the year 2020.

3. York River. The largest existing oil refinery in the Chesapeake Bay Region is located near the mouth of the York River at Yorktown. Although the 50,000 barrel/day refinery is not large by Delaware River of Gulf Coast standards (where plants with capacities of 200,000 barrels/day are not uncommon), the facility still accounted for almost five million short tons of crude petroleum and petroleum products commerce in 1972. Total waterborne commerce on the York River in 1972 totaled 6.5 million short tons of which bulk oil commodities accounted for 5.7 million short tons or approximately 89 percent of the total. Most of the remainder of the traffic was related to the only pulp and paper mill in the Chesapeake Bay

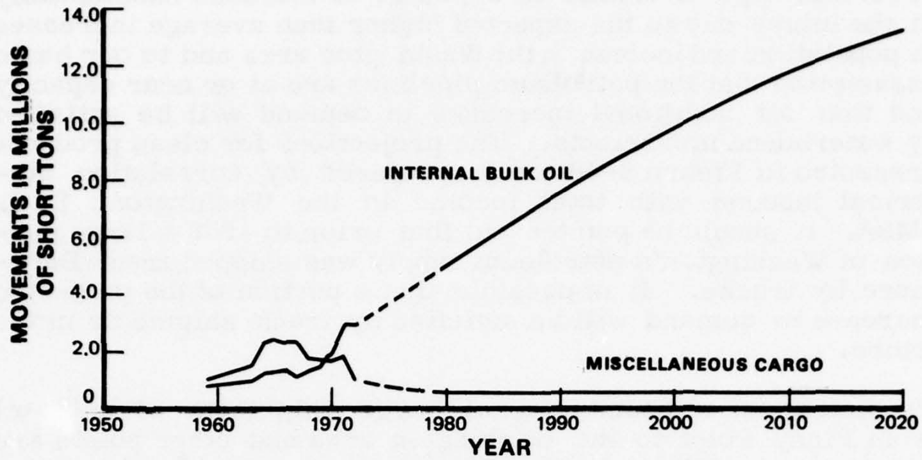


Figure 9-49: POTOMAC RIVER - INTERNAL BULK OIL BARGE SHIPMENTS, MISCELLANEOUS CARGO

Region at West Point, Virginia, at the junction of the Mattaponi and Pamunkey Rivers. The major flows of traffic on the York and the approximate percentage of the total each accounts for are listed below.

a. Crude petroleum, usually from foreign sources to the Yorktown refinery. (40 percent)

b. Coastwise shipments of petroleum products from the refinery to locations in New England. (25 percent)

c. Internal shipments of petroleum products from the refinery to Chesapeake Bay and Delaware River locations. (10-15 percent)

d. Receipts of petroleum products to the refinery from foreign and domestic sources used to help to fill Yorktown refinery orders. (10 percent)

e. Miscellaneous commerce mainly related to the operations of the pulp and paper mill. (10-15 percent)

Most of the vessels carrying crude petroleum into the Yorktown refinery are in the 70,000 dwt class with 41-foot drafts. Petroleum products from the refinery are shipped into New England as far north as Maine in expanded T-2 tankers of about 17,000 dwt with 31-foot drafts. Shorter trips are made in barges holding up to 95,000 barrels with 28-foot drafts. Oceangoing vessels serving pulp and paper mills are in the 5,000 dwt, 21-foot draft size class. The larger crude carriers are unable to fully load due to depth restrictions in the York River channel. (Channel depth is limited to 37 feet.)

As shown in Figure 9-50, waterborne commerce on the York River has increased at a fairly steady rate since 1956 when the Yorktown refinery began operations. Since 1956, the capacity of the refinery has increased by about 45 percent as shown in Figure 9-51. Projections of crude petroleum imports are prepared by first estimating future refinery capacity at Yorktown based on the OBERS projections of refinery output in the Norfolk-Portsmouth Economic Area. Assuming there is currently enough land available at the Yorktown facility to expand to a capacity of about 300,000 barrels/day, refinery capacity is predicted to increase to about 60,000 barrels/day in 1980, to 100,000 barrels/day in the year 2000, and to 166,000 barrels/day in the year 2020. Projections of crude oil imports are presented graphically in Figure 9-50.

Projections of petroleum products shipped by water from the Yorktown refinery are prepared by calculating the percentage of the imported crude oil volume lost to the water transport system both during the refining process and by a change in transport mode after the refining process is completed. Approximately 6 percent of the tonnage is consumed as refinery fuel, 10 percent is processed into coke, and 10 percent of the finished product is transported by tank cars and tank trucks. The remaining quantity, 74 percent, represents the proportion of crude oil import tonnage converted into petroleum products which are shipped from the refinery by water (see Figure 9-50). It is assumed that the breakdown between coastwise shipments and internal shipments remains about the same in the future.

In addition to bulk oil movements related to the refinery, a recent conversion of VEPCO's Yorktown power plant from coal and coke to residual fuel will mean an additional 1.3 million short tons of bulk oil commerce on the York River beginning in the mid-1970's. According to VEPCO officials, however, residual use at the Yorktown plant will decline significantly to about 700,000 short tons in 1980, 500,000 short tons in 1990, and 260,000 short tons in the year 2000 (see Figure 9-50).

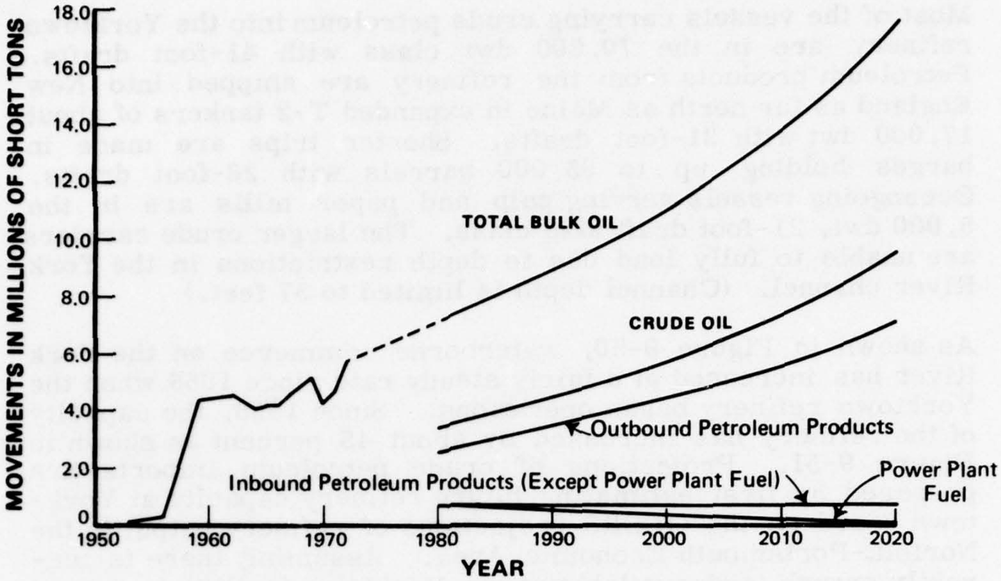


Figure 9-50: YORK RIVER, VIRGINIA - BULK OIL

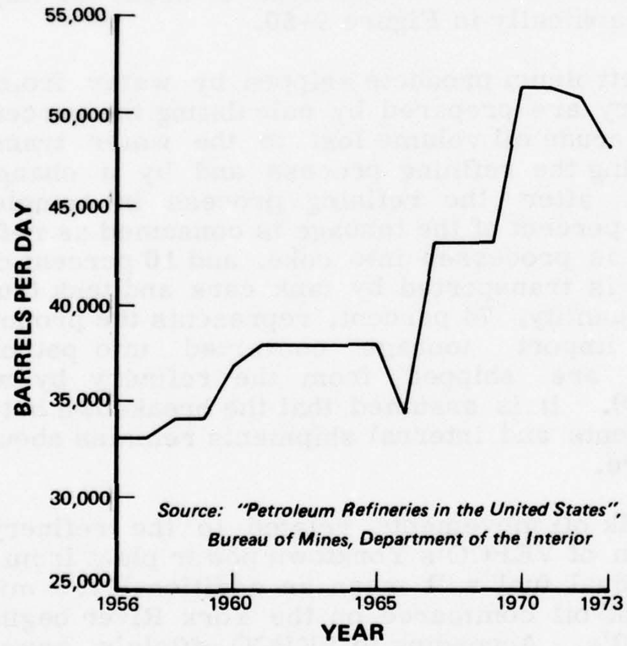


Figure 9-51: CRUDE OIL CAPACITY OF THE YORKTOWN, VIRGINIA REFINERY, 1956-1973

The remainder of the bulk oil movements on the York, approximately 750,000 short tons in 1972, were related primarily to helping the refinery fill its orders. There were also some relatively small movements of residual fuel to the West Point pulp and paper plant as well as some jet fuel movements to the U. S. Navy terminal at Cheatham. The level of traffic has fluctuated between about 825,000 and 450,000 short tons over the last ten years with no significant trend evident. Movements are assumed to continue to fluctuate around the 1970-1972 average of approximately 750,000 short tons.

The remainder of the York River waterborne commerce consists primarily of traffic to and from the West Point pulp and paper mill including foreign exports of pulp and paper products, which totaled about 50,000 short tons in 1972. There were also some relatively small shipments of grains from Port Richmond on the Pamunkey River to Hampton Roads from which it is exported. Movements of these commodities have shown a significant upward trend during the period of record which averaged approximately 5.5 percent annually (see Figure 9-52). Projections were made by extending the historical trend to the year 2020.

4. Wicomico River. Salisbury, the largest town on the Maryland Eastern Shore and a major distribution center for the entire Eastern Shore, is the destination for the vast majority of the commerce transported on the Wicomico River. In 1972, slightly over 800,000 short tons of commerce were shipped on the Wicomico, virtually all of which were classified as internal inbound barge traffic. As shown in Figure 9-53, total waterborne commerce on the Wicomico River has increased steadily during the period of record. The increase has averaged about 5.0 percent annually. Bulk oil commodities from Baltimore, Hampton Roads, and the Delaware River, consisting mainly of gasoline and distillate fuels, accounted for 77 percent of the total traffic. There are no power plants located on the Wicomico River. Fuel distributors in Salisbury serve an area which includes southern Delaware, the southern half of the Maryland Eastern Shore, and the Virginia Eastern Shore. Historical receipts of bulk oil were related to total income in the distribution area during the period to derive the projections shown in Figure 9-53. Other important commodities moved on the Wicomico River not included in the bulk oil category consisted mainly of construction materials such as slag, timber, pilings, sand, gravel, and crushed rock. Since most of the construction materials moved by water are used in the Salisbury area, the tonnage of commodities other than bulk oil were statistically related to population in Wicomico County. These projections are illustrated graphically in Figure 9-53.

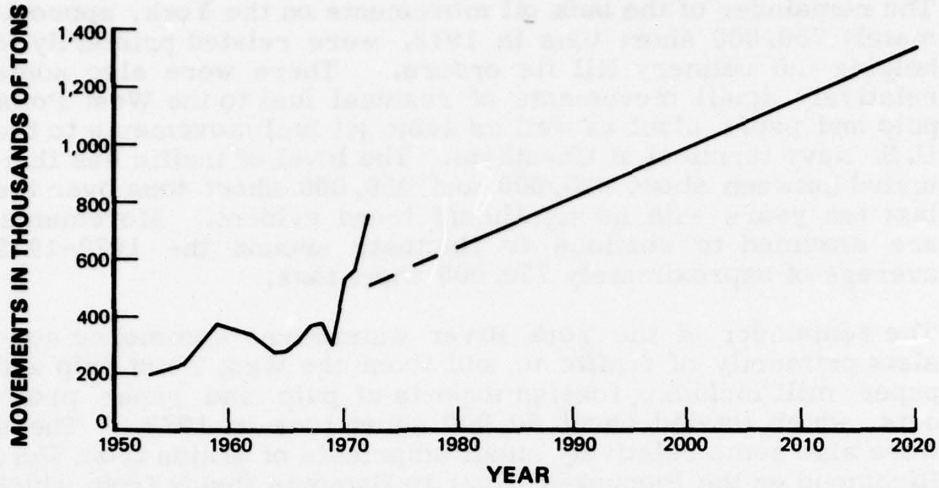


Figure 9-52: YORK RIVER MISCELLANEOUS COMMODITIES (NON BULK OIL)

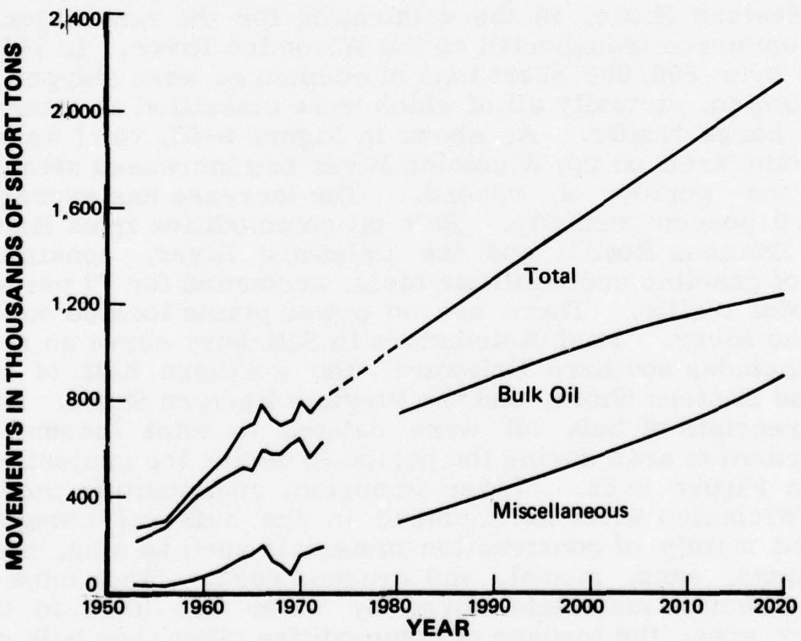


Figure 9-53: WATERBORNE COMMERCE
WICOMICO RIVER (INCLUDING SALISBURY, MD.)

5. Nanticoke River. Waterborne commerce on the Nanticoke River has increased steadily during the 1953-1972 period as shown in Figure 9-54. This increase is a result of steady increases in bulk oil shipments between 1953 and 1968, and then dramatic increases after 1968 as the Delmarva Power and Light Company's power plant at Vienna, Maryland switched from coal, which was brought in by rail, to residual fuel. Bulk oil commodities, mostly residual fuel, comprised almost 90 percent of the total movements on the River in 1972. All of the traffic is classified as internal and 90 percent is inbound. Bulk oil is received at the Vienna power plant and at Seaford, Delaware from Baltimore, Hampton Roads, and Piney Point, Maryland. Most of the traffic other than bulk oil is pulpwood shipped from Sharptown, Maryland (between Vienna and Seaford) to the pulp and paper mill at West Point, Virginia.

The Vienna power plant used approximately 240,000 short tons of residual fuel in 1972. Since the plant is older than average, it is assumed that residual fuel use will decline from its 1972 level down to zero in the year 2000. Since specific data on future residual fuel use by the Vienna plant is not available, the decline in use was based on data received from other power companies. Bulk oil used for purposes other than power generation is generally received at Seaford, Delaware, where it is distributed throughout southern Delaware including Dover, which is one of the fastest growing areas on the Eastern Shore. Large quantities of residual fuel are also used by the DuPont nylon plant at Seaford. Receipts during the 1959-1971 period were correlated with total income in the two southern counties of Delaware. The projections are presented in Figure 9-54.

Outbound shipments of commodities other than bulk oil (i.e., mostly pulpwood) have shown no statistically significant trends over the 1953-1972 average of 125,000 short tons.

6. Rappahannock River. In 1972, approximately 83 percent of the total traffic of 292,000 short tons on the Rappahannock River was inbound. Virtually all of the tonnage moving both ways on the River was transported by barge. Fredericksburg, Virginia, near the head of tide is by far the most important origin and destination point for commerce moving on the Rappahannock.

Approximately 60 percent of the total commerce in 1972 consisted of bulk oil commodities. The remainder was mainly industrial chemicals, pulpwood, and shellfish. A plastics material factory just below Fredericksburg ships large quantities of residual fuel, sulfuric acid, and sodium hydroxide to their plant by water. Besides Fredericksburg, there are no major urban areas or power plants on the Rappahannock River.

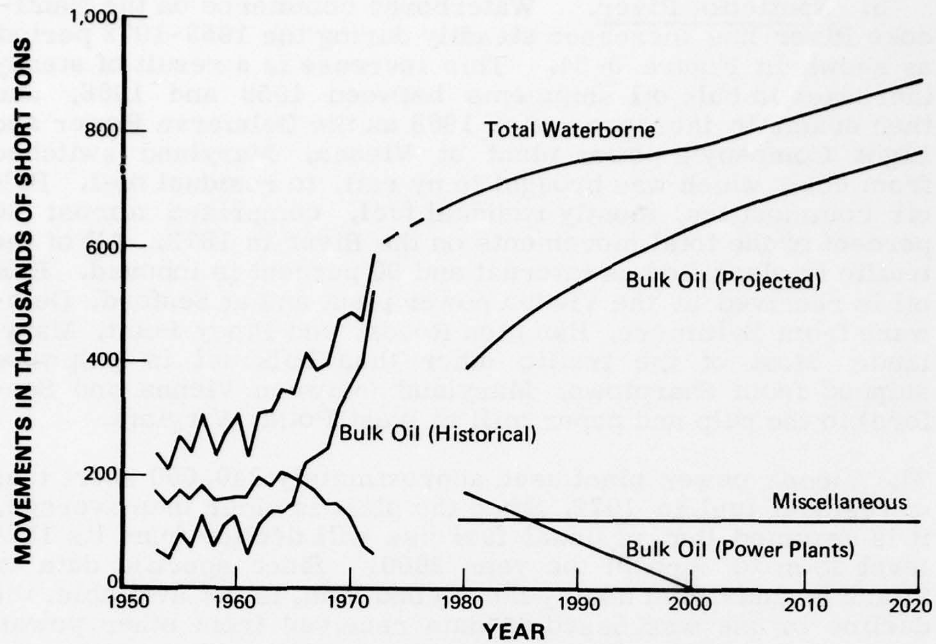


Figure 9-54: WATERBORNE COMMERCE - NANTICOKE RIVER

The Fredericksburg area is connected to the Plantation Pipeline, which as of 1972 supplied the area with virtually all of its demand for "clean" petroleum products (i.e., gasoline, distillate fuel, and kerosene). Residual fuel was the only bulk oil commodity to be transported on the Rappahannock in significant quantities. Total projected demand for petroleum was derived by relating historical inbound movements to total estimated income in the Fredericksburg distribution area, which roughly corresponds to the counties of Stafford and Spotsylvania. Total income is expected to increase at a significantly higher rate in this area than in the Chesapeake Bay Region as a whole, due to its proximity to the fast-growing Washington, D.C. Metropolitan Area. As a result, the projected increase in waterborne movements of petroleum products for the waterway of 4.75 percent annually is one of the highest predicted for the Chesapeake Bay Region.

Movements of commodities other than bulk oil have shown a steady decline during the 1953-1972 period. Traffic is assumed to remain at the 1970-1972 level of approximately 167,000 tons because of the large increases in population projected for the area. Projections are illustrated graphically in Figure 9-55.

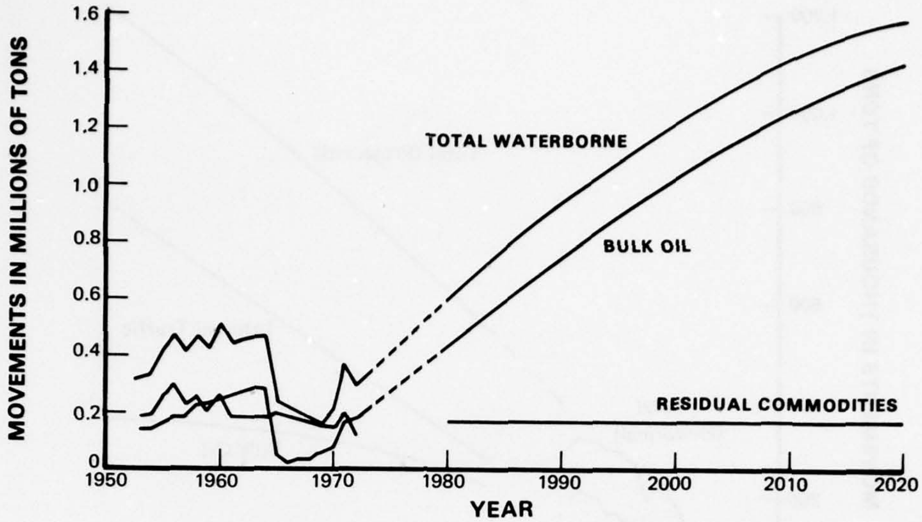


Figure 9-55: WATERBORNE COMMERCE RAPPAHANNOCK RIVER (INCLUDING FREDERICKSBURG, VA.)

7. Choptank River including the Tred Avon River. There were just over 300,000 short tons of waterborne commerce on the Choptank and Tred Avon Rivers in 1972. Virtually all of the traffic was inbound, with about 11 percent being foreign ocean-going imports and the remainder classified as internal barge receipts. Bulk oil commodities, primarily distillate fuel and gasoline, comprised a relatively low (for the smaller waterways) 40 percent of the total waterborne commerce. About 60 percent of the bulk oil movements were destined for Easton on the Tred Avon River. The remainder was received in either Cambridge or Denton. Other important commodity flows on the Choptank and Tred Avon include slag (used for road construction) to Easton and Cambridge, fertilizers to Cambridge, and fresh fish imported from Iceland to Cambridge for processing in one of the two large seafood processing plants in the Cambridge area.

Most of the petroleum products entering Easton and Cambridge are distributed to the four Maryland counties of Queen Annes, Caroline, Talbot and Dorchester. An attempt was made to relate historical movements of bulk oil with total income in the distribution area with poor statistical results. Population was then tried as the independent variable with more acceptable results. This was the model used to formulate the projections shown in Figure 9-56.

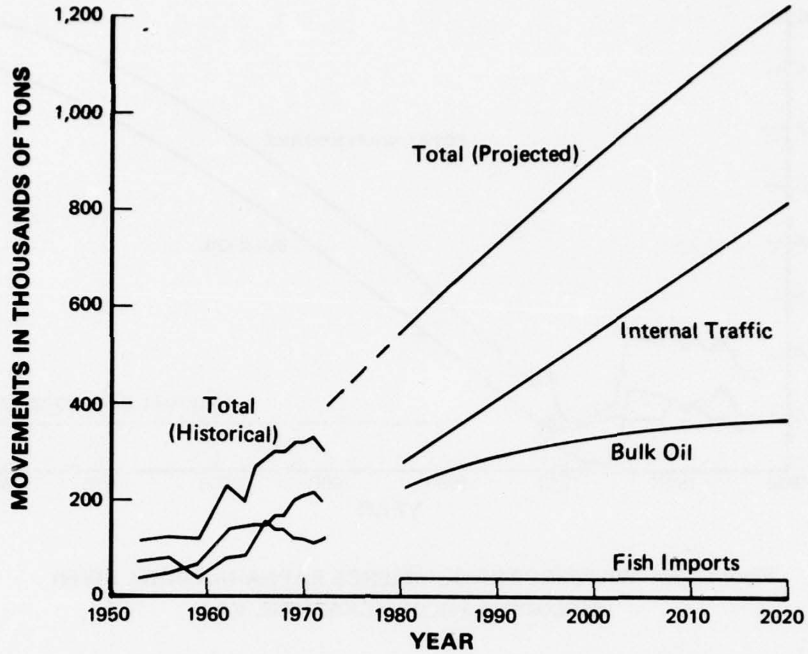


Figure 9-56: WATERBORNE COMMERCE - CHOPTANK AND TRED AVON RIVERS (INCLUDING CAMBRIDGE, MD.)

Oceangoing commerce, which consisted entirely of Atlantic ground fish and tuna imported into Cambridge, was projected separately. The two seafood processing firms distribute their product to much of the eastern half of the United States. As shown in Figure 9-56, imports of fresh fish are projected to decline slowly, but steadily, during the projection period from the 1972 level of approximately 42,000 short tons. The expected decline is due to the negative income elasticities of most of the Atlantic ground fish and the finite capacity of the tunafish resource. The vessels involved in this trade are refrigerated fishing boats which range in size up to 4,100 dwt with 22-foot drafts. These vessels take advantage of the municipal channel in Cambridge which has a project depth of 25 feet.

The remainder of the waterborne traffic, mostly slag, is projected to increase with population in the distribution area. Total projections for the Choptank-Tred Avon system are presented in Figure 9-56.

SUMMARY

In the major ports of Baltimore and Hampton Roads, the movement of the bulk commodities of petroleum, coal, grain, and in the case of Baltimore, iron ore, will continue to dominate waterborne commerce. Bulk oil traffic is expected to show moderate increases in Baltimore, approximately doubling by the year 2020. In Hampton Roads, however, bulk oil commerce will remain at about the 1972 level throughout the projection period due primarily to significant decreases in residual fuel use by the public utilities which will be offset by increases in the demand for the other petroleum products in the area. Coal and grain exports from both ports are projected to experience no growth to only very low growth rates over the projection period. Iron ore imports into Baltimore are also expected to show moderate increases over the next 50 years, increasing from approximately 10 million short tons in 1973 to over 22 million short tons in 2020 (see Sensitivity Analysis section). Total miscellaneous bulk commerce passing through both port complexes is predicted to increase at a rate roughly proportional to population growth in the various distribution areas.

Despite the fact that the bulk commodities will continue to comprise the majority of Hampton Roads and Baltimore commerce, foreign general cargo traffic will represent a steadily increasing share of the total tonnage. Shipments of these commodities are projected to increase by a factor of approximately six in both Baltimore and Hampton Roads. The majority of this traffic is expected to be containerized.

Bulk oil is projected to continue to dominate traffic movements through the minor ports and waterways around Chesapeake Bay. The largest increases are expected on the Western Shore due to larger increases in population and income predicted for these areas compared to the Eastern Shore. The York River is projected to experience very large increases in bulk oil shipments due to a projected expansion of the Yorktown refinery.

It should be noted that the projections presented in this report are intended to serve only as an indication of future problem areas. Further refinement of these projections is required in order to use them as a basis for the evaluation of specific navigation plans or improvements.

FUTURE SUPPLY

In this Appendix, the future supply analysis is actually an analysis of the capacity of a harbor or waterway in terms of channel dimensions. The following section will present an inventory of existing and proposed channel depths for the major waterways and harbors in the Chesapeake Bay Region.

ASSUMPTIONS AND METHODOLOGY

To assess the present and future capacity of the waterborne commerce system in the Chesapeake Bay Region, an inventory was made of authorized channel depths for the major waterways and harbors in the area. These data were gathered from such sources as the Maryland and Virginia Port Authorities, various pilot associations, Army Corps of Engineers' publications, and private firms which ship materials by water. This inventory is presented in Table 9-6.

The basic assumption made in this assessment of future supply is that there will be no further development of the Bay's navigation system beyond the channel improvement projects which are currently authorized. These "without project" projections of supply can then be compared to the "with project" demand projections (see Chapter II for a discussion of how the demand projections reflect "with project" conditions) to identify specific areas or types of uses where future use may be greater than the existing capacity of the resource.

FUTURE SUPPLY

As shown in Table 9-6, there are a great variety of channel depths in the Chesapeake Bay Region depending on the waterway and the commodity or commodities being transported. Baltimore and Hampton Roads contain the only major deepwater ports in the study area with main channel depths of 42 and 45 feet, respectively. The dimensions of both public and private branch channels within these port complexes vary considerably,

TABLE 9-6
AUTHORIZED CHANNEL DEPTHS AND PRESENT VESSEL SIZES
BY COMMODITY FOR MAJOR HARBORS AND WATERWAYS

COMMODITY	AUTHORIZED DEPTH AT COMMODITY DOCK	PRESENT VESSEL TYPE	PRESENT VESSEL SIZE[1]	REMARKS
BALTIMORE HARBOR				
Residual Fuel	42' to 34'	Tankers (Foreign)[2]	25-55,000 dwt Up to 42' drafts	Vessel size restricted by present channel depth.
	42' to 34'	Tankers (Coastwise)[3]	30-50,000 dwt with up to 39' drafts and 75,000 dwt with 46' drafts	Depth limitations on Gulf Coast restrict loaded drafts to 39 feet.
	Variable	Barges (Internal)[4]	Up to 28,000 dwt with 25' drafts	Barge traffic is not limited by present channel depths.
Crude Oil	34' to 30'	Tankers (Foreign)	20-30,000 dwt Up to 35' drafts	
Other Petroleum Products	42' to 34'	Tankers (Coastwise)	30-50,000 dwt Up to 39' drafts and 75,000 dwt with 46' drafts	Vessel size restricted by present channel depth.
	Variable	Barges	Up to 28,000 dwt with 25' drafts	Not limited by present channel depths.
Coal	42' to 35'	Dry Bulk	35-55,000 dwt Up to 42' drafts	Vessel size restricted by present channel depth. World fleet has ships to 200,000 dwt range with 60' drafts.

[1]Vessel sizes reflect the typical ship encountered in the trade.
[2]Foreign trade either imports or exports.
[3]Coastwise traffic generally between Gulf Coast and Chesapeake Bay.
[4]Internal barge traffic in Chesapeake Bay and Inter-Coastal Waterway.

TABLE 9-6 (cont'd)
AUTHORIZED CHANNEL DEPTHS AND PRESENT VESSEL SIZES
BY COMMODITY FOR MAJOR HARBORS AND WATERWAYS

COMMODITY	AUTHORIZED DEPTH AT COMMODITY DOCK	PRESENT VESSEL TYPE	PRESENT VESSEL SIZE	REMARKS
BALTIMORE HARBOR (cont'd)				
Iron Ore	42' to 38'	Dry Bulk (Foreign)	40-60,000 dwt Up to 42' drafts	Vessel size restricted by present channel depth. World fleet has ships to 200,000 dwt with 60' drafts.
Non-Ferrous Ores	42' to 25'	Dry Bulk (Foreign)	20-40,000 dwt 32' to 36' drafts	
Grain	37' to 32'	Dry Bulk (Foreign)	15-30,000 dwt 28' to 36' drafts	Vessel size restricted by present channel depth.
Salt, Gypsum and Sugar	32' to 27'	Dry Bulk (Foreign)	10-35,000 dwt 25' to 35' drafts	Sugar carriers must occasionally light load due to depth limitations.
General Cargo	32' to 27'	Containers	15-20,000 dwt Up to 32' drafts	Not limited by present channel depths.
HAMPTON ROADS				
Residual Fuel and Other Petroleum Products	45'	Tankers (Foreign)	75,000 dwt Up to 46' drafts	Vessel size restricted by present channel depth.
	45'	Tankers (Coastwise)	30-50,000 dwt Up to 39' drafts and 75,000 dwt with 46' drafts.	Depth limitations on Gulf Coast restrict loaded drafts to 39 feet.

TABLE 9-6 (cont'd)
AUTHORIZED CHANNEL DEPTHS AND PRESENT VESSEL SIZES
BY COMMODITY FOR MAJOR HARBORS AND WATERWAYS

COMMODITY	AUTHORIZED DEPTH AT COMMODITY DOCK	PRESENT VESSEL TYPE	PRESENT VESSEL SIZE	REMARKS
		HAMPTON ROADS (cont'd)		
	45'	Barges (Internal)	Up to 28,000 dwt With 25' drafts	Barge traffic not limited by present channel depths.
Coal	46' to 36'	Dry Bulk (Foreign)	50-75,000 dwt 38' to 46' drafts	Vessel size restricted by present channel depth. World fleet - 150 to 200,000 dwt with drafts of 55' to 65'.
Grain	40' to 45'	Dry Bulk (Foreign)	25-35,000 dwt 32' to 36' drafts	Vessel size restricted by present channel depth.
Gypsum and Cement	35'	Dry Bulk (Foreign)	15-35,000 dwt Up to 27' drafts	Not limited by present channel depths.
General Cargo	40' to 35'	Container	15-35,000 dwt Up to 37' drafts	Not limited by present channel depths.
		YORK RIVER TO YORKTOWN		
Crude Petroleum	22'*	Tankers (Foreign)	30-45,000 dwt Drafts to 37'	Vessel size restricted by present channel depth.
Petroleum Products	22'*	Tankers (Foreign)	30-45,000 dwt Drafts to 37'	Residual fuel to Yorktown power plant.
	22'*	Tankers (Coastwise)	Up to 17,000 dwt With 31' drafts	Not limited by present channel depths.
	22'*	Barges (Internal)	Drafts 14' to 28'	Not limited by present channel depths.

*Naturally deep waters occur to 37'.

TABLE 9-6 (cont'd)
AUTHORIZED CHANNEL DEPTHS AND PRESENT VESSEL SIZES
BY COMMODITY FOR MAJOR HARBORS AND WATERWAYS

COMMODITY	AUTHORIZED DEPTH AT COMMODITY DOCK	PRESENT VESSEL TYPE	PRESENT VESSEL SIZE	REMARKS
		WICOMICO RIVER		
Petroleum Products Other Commerce	14'	Barges (Internal)	Drafts 10' to 11'	Controlling depth approximately 10'.
		NANTICOKE RIVER		
Petroleum Products and Other Commerce	12' to Seaford, Delaware	Barges (Internal)	Drafts 6' to 11'	Largest barges unload at Vienna, Maryland.
		RAPPAHANNOCK RIVER		
Petroleum Products and Other Commerce	12' to Fredericksburg, Virginia	Barges (Internal)	Drafts 6' to 11'	Largest barges unload just south of Fredericksburg.
		CHOPTANK RIVER		
Fresh Fish	25' at Cambridge, Maryland and	Refrigerated (Foreign)	Up to 4,100 dwt With 22' drafts	Not limited by present channel depths.
Petroleum Products and Other Commerce	8' to Denton, Maryland	Barges (Internal)	Drafts 6' to 11'	

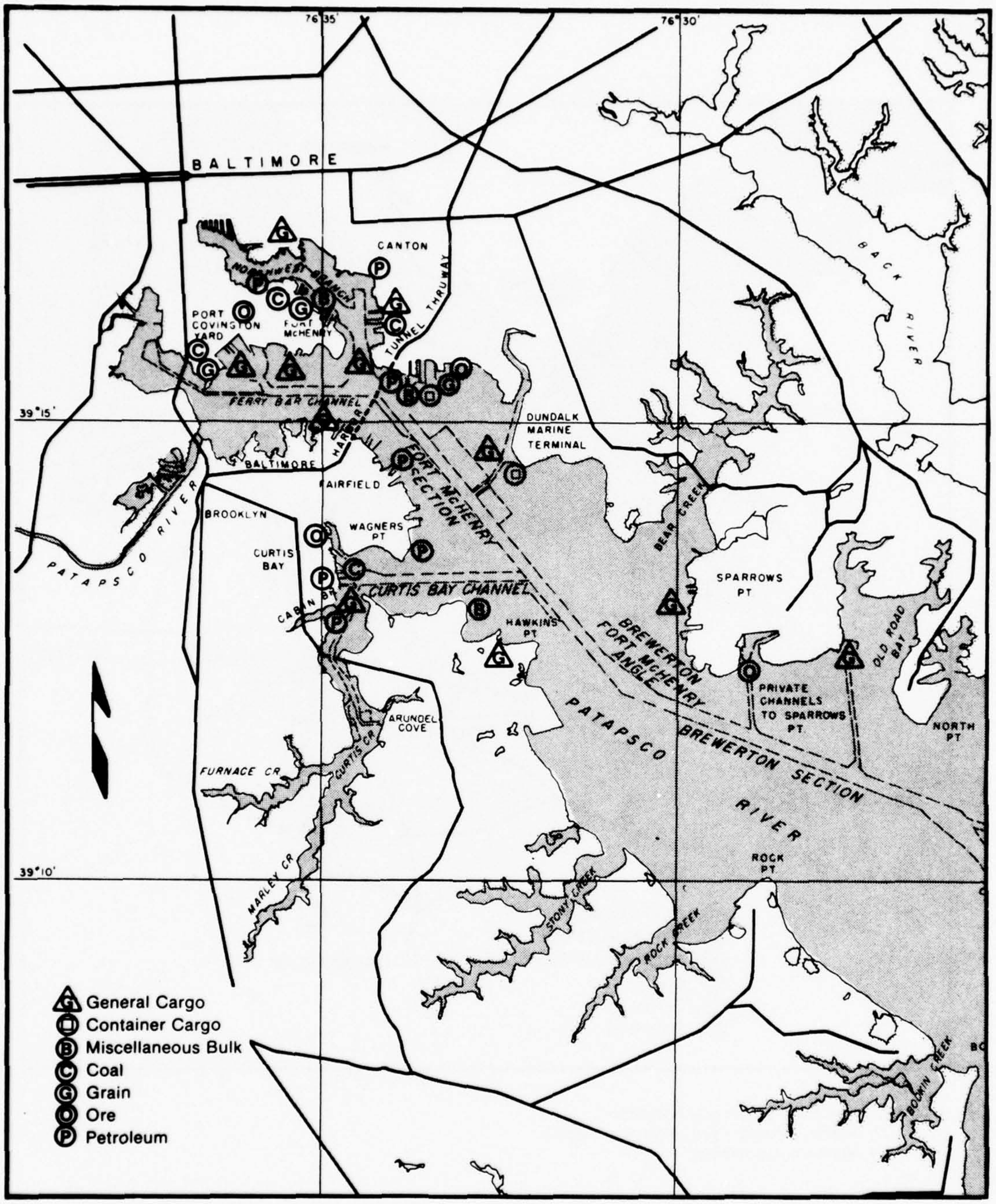
TABLE 9-6 (cont'd)
AUTHORIZED CHANNEL DEPTHS AND PRESENT VESSEL SIZES
BY COMMODITY FOR MAJOR HARBORS AND WATERWAYS

COMMODITY	AUTHORIZED DEPTH AT COMMODITY DOCK	PRESENT VESSEL TYPE	PRESENT VESSEL SIZE	REMARKS
CHESAPEAKE AND DELAWARE CANAL				
Petroleum Products and Other Commerce	35'	Barges (Internal)	Up to 250,000 barrel capacity with 33' drafts	Not limited by present channel depths.
General Cargo	35'	Containers	15-20,000 dwt Up to 32' drafts	"
Coal	35'	Barges (Coastwise and Internal)	Drafts up to 20'	"

and as shown on Figures 9-57 and 9-58 the major terminal facilities are not confined to one geographical area. With the exception of the Chesapeake and Delaware Canal, which serves primarily Port of Baltimore, and the York River channel, which handles petroleum almost exclusively, the remaining channels are 25 feet in depth or less and handle barge traffic almost exclusively.

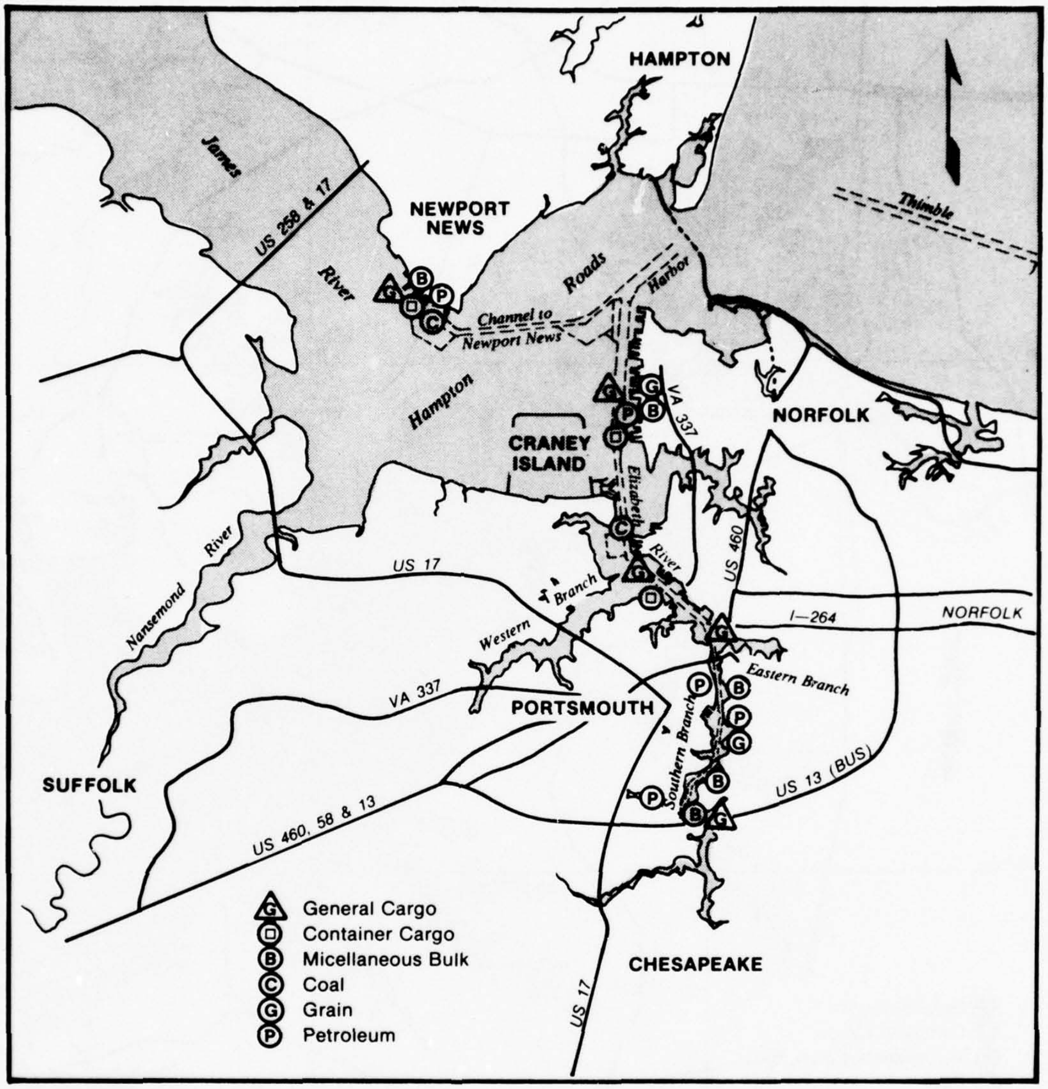
In many areas, especially Baltimore Harbor and some of the smaller waterways and harbors, serious silting of the channels has occurred which has significantly altered channel dimensions. For example, the main channel to Baltimore, which has an authorized depth of 42 feet, now has a controlling depth of 40 feet in several areas. Most of the branch channels to Baltimore Harbor have also silted in at least several feet over their authorized depth. The problem is further compounded because of the lack of a suitable disposal site for the dredge material from the channels. Many of the companies importing or exporting raw materials into the Port of Baltimore have had applications for dredging permits (for either maintenance or deepening) rejected because of the lack of a suitable disposal site. A project to deepen the main channel to Baltimore from 42 feet to 50 feet, the branch channel into Curtis Bay from 42 feet to 50 feet, the East Channel of the Northwest Branch from 35 feet to 49 feet, and the West Channel of the Northwest Branch from 35 feet to 40 feet, has been authorized by Congress and preconstruction planning will be initiated in Fiscal Year 1977. The problem of a spoil disposal area for the dredge material from this project will be resolved during the preconstruction planning phase.

The smaller waterways and harbors included in this analysis have also experienced serious silting problems. For example, the authorized depth in the Nanticoke River to Seaford is 12 feet. The controlling depth in this stretch of waterway, however, is only 7 feet. The controlling depth in the Wicomico River is two feet less than the authorized depth; in the York River to West Point, Virginia, the difference is almost five feet; while at the municipal pier in Cambridge, Maryland, the difference is three feet. In these areas, as in most of the minor waterways around Chesapeake Bay, with the exception of the Potomac River, the availability of a disposal site for the dredge material is not as critical as in the major harbors because the amount of material is significantly less and is generally not polluted. There are several reasons for the discrepancy between authorized depths and controlling depths in these waterways. First, because of the large number of Federal navigation projects in the Corps of Engineers' Baltimore and Norfolk Districts, it is virtually impossible because of annual funding limitations to maintain all the channels to their



SOURCE: Port of Baltimore Handbook—1975, Maryland Department of Transportation

Figure 9-57: LOCATION OF CHANNELS AND MAJOR TERMINAL FACILITIES BALTIMORE, MARYLAND



SOURCE: The ports of Greater Hampton Roads—Annual 1975, Hampton Roads Maritime Association

Figure 9-58: LOCATION OF CHANNELS AND MAJOR TERMINAL FACILITIES HAMPTON ROADS, VIRGINIA

authorized depths. Second, some of the waterways have not experienced the level of traffic which would justify frequent maintenance dredging.

During fiscal years 1974 and 1975, the main channels in several of these waterways were dredged. The Tred Avon River was recently dredged to its new project depth of 12 feet from the old depth of 8 feet. Some part of the 25-foot main channel of the James River is usually maintained every year. The James currently has an authorized depth of 35 feet. However, a follow-up study completed in 1972 found that dredging to the 35 foot depth was no longer economically justified. The Wicomico and the Delaware portion of the Nanticoke were dredged in 1976. The level of deep draft commerce on the upper reaches of the York River has not been sufficient to justify frequent maintenance dredging. A study of petroleum movements on the York River by the Norfolk District of the Corps of Engineers resulted in a recommendation that the York River entrance channel be improved by providing a two-lane, two-level channel into the river; the inbound lane to provide a depth of 50 feet, and the outbound lane a depth of 37 feet. However, these recommendations are subject to further investigation if the major Hampton Roads channels are recommended and authorized for deepening beyond depths of 45 feet.

The Baltimore District is currently undertaking a study to determine the feasibility of the Federal Government assuming the responsibility for the maintenance of the municipal channel at Cambridge, Maryland, on the Choptank River. Also, maintenance dredging on the Potomac has not been undertaken in recent years largely because of a lack of a dredge material disposal site and relatively low levels of traffic.

Dredging of the C & D Canal to the new project depth of 35 feet from 27 feet was recently completed. However, the approach channel to the Canal from Baltimore has experienced serious shoaling. The newly deepened C & D Canal cannot be used efficiently unless the approach channel is dredged to the 35 foot project depth.

Authorized depths of the main channels in the Hampton Roads complex are 45 feet from deepwater in Hampton Roads to Lambert Point and Newport News, and 40 feet from Lambert Point to the Norfolk and Western Railroad Bridge crossing of the Southern Branch of the Elizabeth River. Branch channels range from 12 to 35 feet. The Norfolk District is currently investigating the feasibility of deepening the Hampton Roads channels. The existing channels in the Hampton Roads complex have not had the maintenance dredging problems encountered in the Baltimore Harbor mainly because of the existence of a

large diked disposal site at Craney Island (see Figure 9-58). It should be noted, however, that the existing Craney Island Disposal Area will be filled to capacity by about 1980 and the location of an adequate replacement has yet to be resolved.

FUTURE NEEDS AND PROBLEM AREAS

There are several types of commodity movements on Chesapeake Bay in which existing capacities of the waterborne transportation system, in terms of channel sizes, are unable to handle present or projected levels of commerce, in terms of ship sizes and tonnages, without serious losses in economic efficiency. These losses in efficiency develop when large vessels must enter or leave a port only partially loaded because of depth limitations. When these efficiency losses are severe enough to outweigh any competitive advantage an area might have for the movement of a certain commodity, severe economic consequences may result. These consequences may include the partial or complete loss of commodity-related business, including truck, rail, banking, brokerage, and other related services. In the case of imported raw materials processed in the port area, economic losses may be severe enough to cause cutbacks in production or even plant closings resulting in the loss of jobs, income, and tax revenues.

The most critical commodity movements through the Ports of Baltimore and Hampton Roads, are the bulk commodities such as iron ore, coal, grain, and petroleum products. Most of the larger vessels carrying these commodities into the two ports cannot fully load or must lighter before entering the harbor.

As discussed in the previous section, a survey report prepared by the Baltimore District in 1969, found that the optimal depth of Baltimore's main channel was 50 feet, given the existing physical, economic, and environmental constraints as well as

projected levels of commerce and vessel sizes. Optimal depths of the branch channels were found to be as described in the previous section. Iron ore, coal, petroleum products, and sugar will be the major beneficiaries of the authorized deeper channel for Baltimore Harbor. This project, if constructed, will eliminate most of the serious inefficiencies associated with the movements of these commodities at the present time. The major piers handling ore, except for the Port Covington pier owned by the Western Maryland Railway, will be provided with a main channel of 50 feet. The coal piers will have access to at least a 49-foot channel, again excepting the Port Covington pier which currently has available a 42-foot main channel depth which is not recommended for deepening. Grain movements through the Locust Point and Canton facilities will also benefit from a deeper channel. Although only the Locust Point pier makes full use of the existing main channel depth, the companies controlling the other grain piers have shown an interest in deepening their approach channels.

Considering projected volumes of commerce, present main channel dimensions are expected to be sufficient to handle future shipments of the miscellaneous bulk commodities. The only exception to this generalization is sugar. The Baltimore Harbor and Channels Report recommended deepening of the existing channel to the large sugar refinery from 35 to 40 feet.

There are two major container facilities in the Baltimore Harbor, Dundalk Marine Terminal and Sea-Land Service. The Dundalk complex has a depth of 34 feet, while the Sea-Land facility has 32 feet. Both facilities, however, have a 42-foot main channel available which is authorized to be deepened to 50 feet. It is unlikely that channel depths of greater than 40 feet will be needed for the vast majority of container vessels in the foreseeable future. (39)

Given that the need for a deeper channel has been recognized, the major navigation-related problem facing Baltimore Harbor in the near future is the disposal of dredged material. Since the channel deepening to 42 feet was completed in 1965, serious shoaling of the channels has occurred in several areas. Shoaling in the channels has caused numerous bottom scraping episodes and has reportedly caused the loss to Baltimore of millions of dollars worth of port-related commerce and business. Maintenance dredging by the Corps of Engineers and other public and private interests has been repeatedly delayed because of the lack of agreement on an economically and environmentally acceptable disposal site for the dredged material. Recently, in early 1975, after many months of delay the Corps was able to perform maintenance dredging on some of the more critical areas in the main channel which had shoaled to about

40 feet. The approximately 850,000 cubic yards of dredge material removed were disposed of in open water off Kent Island, Maryland. This area has been used many times during the past 25 years as a disposal area for uncontaminated dredge spoil but opposition has been especially strong in recent years due to the belief that the dredge material from the maintenance dredging was, in fact, too contaminated for the Kent Island area. Another area in the vicinity of Pooles Island has been set aside for the open water disposal of contaminated material although access to the area by hopper dredge is hampered by shallow water. If the 50-foot project is completed, it is estimated that approximately 90 million cubic yards of material will be dredged (including maintenance) from Baltimore Harbor and nearby associated channels during the next 20 years. It is estimated that maintenance dredging with a fifty-foot project will account for an average of 2 million cubic yards of material annually. (40) Extending these figures out to the year 2020 gives an estimate of approximately 150 million cubic yards of dredge material to be disposed of during the projection period. This quantity of material is sufficient to cover the entire City of Baltimore to a depth of approximately 2 feet. None of the dredging can take place, however, until a suitable disposal area is identified.

A diked disposal site adjacent to Hart and Miller Islands just north of the Patapsco River has been recommended by the State of Maryland but has not yet been approved by all the appropriate Federal agencies. The Hart-Miller site will have a maximum capacity of approximately 52 million cubic yards. The dimensions of the diked area are approximately 12,430 feet by 4,700 feet with an elevation of 18 feet above mean low water. The disposal area is provided with three sluice gates. As the dike approaches maximum capacity (during the last 30 percent of its life) the effluent will discharge to the Bay through the sluice gates. This effluent will be treated to equal or exceed the water quality standards. The sluice gates will be non-functional during the initial period of operation because liquid will be filtered through the porous sand dike walls. Construction will take about 2 years. The project life is estimated to be 9-10 years if dredged material from the authorized 50-foot deep Baltimore Harbor Channel project is placed within the enclosure; if the project is used for only maintenance dredge material, however, the project life will be 20-30 years. The planned purpose of the disposal site after completion is for recreation. It should be pointed out that although the Hart-Miller area is currently being used extensively by picnickers and recreational boaters, the two islands have serious erosion problems and are expected to cease to exist by the year 2000.

According to the figures presented above, the Baltimore Harbor area will need at least one, and possibly two, other disposal sites the size of the Hart-Miller complex. There are many options open to the State of alternative methods of disposal, as discussed in Chapter IV of this Appendix.

Inefficiencies in the movement of export coal through Hampton Roads will be greatly alleviated if a deeper channel is authorized and funded. The deeper channel is planned to serve the major coal piers at Newport News and Lambert Point. The channel will also benefit the movement of crude oil through Hampton Roads to the refinery at Yorktown on the York River by allowing larger tankers (i.e., up to 90,000 dwt) to enter Hampton Roads where they can be lightered for the trip to Yorktown. This plan was found to be more economical than the alternative of deepening the York River channel to the desired depth. One disadvantage of the plan is the possibly damaging environmental consequences of a major oil spill during these lightering operations. Several environmental, private, state, and local groups in the Hampton Roads area preferred the dredging alternative to the lightering plan because of the oil spill possibility.

Only one of the two grain piers in the Hampton Roads complex, the Continental Grain Company located at Sewells Point, will have the opportunity to make use of the proposed deeper channel. The Cargill Grain Company is currently in the process of deepening its berth and access channel to 40 feet to make full use of the existing 40-foot channel. In addition, Cargill has also enlarged its pier from the Norfolk and Western Railroad.

All of the piers handling cement and gypsum in Hampton Roads, except one cement pier, have access to a 40-foot main channel. The one pier handling cement is located next to a 35-foot main channel. It is unlikely, considering the projected volumes of traffic, that deeper depths than those now existing will be required by firms handling these two commodities.

The Elizabeth River Terminals, which handle movements of fertilizers and miscellaneous general cargo items, have expressed a need for a deepening of the existing 35-foot channel to 40 feet to handle vessels in the 35,000 dwt class. The Norfolk Harbor and Channels survey study is considering improvements to the existing channels.

Approximately 64 percent of the foreign general cargo moving through Hampton Roads in 1974 was containerized. There are three major container terminals in the area, the Norfolk International Terminals, the Portsmouth Marine Terminal, and the Newport News Terminal. Each of these facilities currently

have 35-foot depths at the berths and access to at least a 40-foot main channel. The Norfolk and Newport News facilities will have access to the 55-foot channel if that project is authorized and funded. As in the Baltimore Harbor case, the container vessels carrying general cargo in and out of Hampton Roads are not expected to increase significantly in size in the foreseeable future. Therefore, it is not expected that channel depths will be a significant constraint to the movement of containers through Hampton Roads.

The existing dredge material disposal situation is not nearly as critical in the Hampton Roads area as in Baltimore. This is due to the existence of the Craney Island Disposal Area. The Craney Island site, which was completed in 1957, is a Federally authorized project located in the heart of the Hampton Roads port complex. The site is nearing its capacity of 125 million cubic yards, however, with complete filling expected in the late 1970's. Dredge material disposal will again become a serious problem in the Hampton Roads area starting around 1980.

Maintenance dredging for the existing authorized channels in the Hampton Roads area will amount to about 2.6 million cubic yards annually during the 1980-2020 period. If the recommended plan of channel deepening to 55 feet for Hampton Roads is authorized by Congress, dredged material to be disposed of will increase by 81.2 million cubic yards for new work and about 1.4 million annually for additional maintenance.(41) This amounts to a total of approximately 104 million cubic yards of dredge material to be disposed of by the year 2020 with the existing channels and a total of 227 million cubic yards during the same period with the 55 foot channel.

In a study being conducted by the Norfolk District of potential disposal sites after the Craney Island site reaches capacity, one alternative considered is to expand the capacity of the existing Craney Island site by gradually increasing the elevation of the containment levees as the need develops. This method will increase the capacity of the site by approximately 42 million cubic yards. This is obviously only a short-term solution, however, as the channel deepening project alone (if authorized and funded) will create almost twice the additional capacity of dredge material. Assuming only maintenance dredging of the existing channel, the expanded Craney Island site will reach capacity in about 11 years. The study will also recommend the continued study of at least eight other alternatives. Any of these alternatives could meet the disposal needs of Hampton Roads for a period of about 40 years or more. According to the figures presented above, the presently authorized channels in the Hampton Roads area will need a

disposal area or areas with a volume approximately 20 percent larger than the existing Craney Island site. If the 55-foot project is authorized and funded, a capacity more than double the Craney Island site will be needed by the year 2020.

Until recently, the Chesapeake and Delaware Canal was restricted to a relatively shallow, from an international trade point of view, 27-foot channel. With the recent deepening and widening of the channel completed, however, it is believed that channel dimensions will not be a constraint to the general cargo vessels and petroleum products carriers which use the Canal. Most of the petroleum products are transported by barges with drafts of up to 28 feet. The largest vessels carrying general cargo through the Canal are the containerships in the 15-20,000 dwt range with drafts of less than 30 feet. The container vessels in the Northern Europe to Baltimore trade route, which often pass through the C & D Canal, are generally smaller than the containerships from Japan which can range up to 35,000 dwt with fully-loaded drafts of over 35 feet. Since almost all of the containerships now in service were built during the last 5 to 10 years and have a useful lifespan of about 25 years, it is expected that there will be no significant increase in the size of the container fleet using the Canal for at least the next 15 to 20 years.

The most immediate waterborne commerce related problem facing the York River is the lack of sufficient channel depth to allow large tankers to bring crude petroleum and petroleum products directly to the refinery and power plant without lightering. As part of the on-going Norfolk Harbor Study, it appears that if the Hampton Roads channel is deepened beyond 50 feet, the most economically acceptable alternative is a combination of lightering and deepening the York River entrance channel. It should be noted that the projections presented in this appendix, however, are significantly higher than those in the Norfolk Study since the latter assumes no expansion of refinery capacity.

A potential problem area, which may develop in the vicinity of Yorktown, concerns the significant increase in crude petroleum receipts and petroleum product shipments projected for the future. An increase in this type of traffic, estimated to rise almost 100 percent by 2000 and over 200 percent by 2020, means the potential for oil spills also increases. The area of the York River around Yorktown supports important commercial (including shellfish) and sport fisheries which could be adversely affected by an oil spill. In addition, the location of the refinery and power plant near the mouth of the river could make a major spill during the spawning runs especially serious if it interferes with the fish entering the River.

The ability of the existing channels in the so-called "minor" ports and waterways on the Western Shore of the Chesapeake Bay to meet future demands depends in large measure on the proportion of the demand for petroleum products which will be met by pipeline. If pipeline capacities increase significantly then it can be expected that the existing channels will be able to meet future demands.

The projected levels of shipments of general cargo commodities for these waterways will probably not justify, by themselves, deeper channels. The growing use of containership, roll-on/roll-off vessels, and barge carriers (e.g., LASH) tends to centralize port activity around a few major coastal ports because of the large capital investments in port equipment and land which must be made. As a result, the smaller ports, such as Richmond, Hopewell, Fredericksburg, and Alexandria, tend to be bypassed in favor of the larger ports such as Baltimore and Hampton Roads except for those commodities which are either produced or processed in the vicinity of the smaller port. An additional constraint on the development of the channel of these waterways is their long length through relatively shallow water.

On the Eastern Shore of the Chesapeake Bay the major commodity group transported has been and is expected to remain petroleum products. The mode of transport will most probably remain shallow-draft barges. Because of the relatively low levels of population and income in this area, the demand for petroleum products is projected to be significantly lower than on the Western Shore. The Eastern Shore is not served by a petroleum pipeline, and therefore, a major portion of the increased demand is expected to be satisfied by waterborne shipments. Some of the petroleum products consumed on the Eastern Shore are distributed by tank truck from the Delaware River area. This mode of transport could also handle a large portion of the increase in petroleum traffic.

There is a critical need on several of the Eastern Shore rivers, most notably the Wicomico, for maintenance dredging. There have been several instances of oil spills in the Salisbury, Maryland area on the Wicomico caused by barges hitting bottom at less than project depths. Because of the relatively clean dredge material from the Eastern Shore rivers, there are generally few problems associated with its disposal. In fact, the Baltimore District of the Army Corps of Engineers has many requests for dredge material by Eastern Shore residents for use as fill. Maintenance dredging is due to begin on the Wicomico River shortly.

POTENTIAL DEVELOPMENTS

At the present time, Chesapeake Bay has only one petroleum refinery of any significant size, the Yorktown facility with a 50,000 barrel per day capacity. There are currently, however, three other refineries being considered in the Bay Region having a total additional capacity of approximately 475,000 barrels/day. If these refineries are built and become operational, approximately 25 million additional tons of crude petroleum a year will need to be shipped on the Bay's waters. In addition, some proportion of the refined products will be shipped by water. A refinery typically uses about 6 percent of the total tonnage passing through the facility as fuel. Conceivably, as much as 94 percent of the 25 million tons, or about 23.5 million tons of products, could be shipped by water although the actual total of products will probably be considerably less.

The largest of the proposed refineries is a Crown Petroleum plant being considered for the Baltimore area. The plant would have a capacity of 200,000 barrels of crude/day. The firm is planning to bring very large tankers from the Near East into a deepwater port in Nova Scotia or the Bahamas. From the deepwater port the crude will be transported to the refinery in smaller tankers in the 48,000 to 60,000 dwt range. It is expected that an average of five ships will be calling on the facility every week. The market area served by this refinery is planned to extend roughly 100 miles around Baltimore. If and when the land is acquired, there will be an interval of 3 to 4 years before the plant is operational.

The second largest proposed refinery in the Bay Region is a facility in Portsmouth, Virginia, with a planned capacity of 175,000 barrels/day. The plant will be located on land already acquired by the developers, the Hampton Roads Energy Corporation. The land is located just south of Craney Island on the Elizabeth River. The refinery will have the facilities to handle two 85,000 dwt tankers/week probably from the Near East. Refined products will be distributed throughout the Mid-Atlantic area with an estimated 75 to 80 percent moving by barge or tanker. The Hampton Roads Energy Corporation is currently waiting for permit approval before beginning construction.

The remaining proposed refinery is planned to be located at Piney Point, Maryland, on the Potomac River, the present site of a petroleum storage and distribution facility. This

refinery is planned to have a capacity of 100,000 barrels/day. The proposal to locate the plant in this area has generated a great deal of opposition on environmental grounds from residents of the surrounding area which is now oriented toward farming, fishing, and recreational activities.

Still another facility to handle petroleum products, although of a different type, is scheduled to begin operations at Cove Point, Maryland, during the first part of 1977. This facility, located just south of Baltimore, is being constructed by the Columbia Liquid Natural Gas Corporation. Liquid natural gas (LNG) tankers with 36-foot drafts and a capacity of approximately 4.4 million cubic feet will bring this commodity from Algeria to Cove Point where the gas will be distributed to a seven state area. Because of the extremely low temperatures involved, there is virtually no danger of a spill (i.e., the liquid gas would vaporize upon contact with the much warmer air). There is some potential damage, however, of a fire or explosion in the event of a collision with another vessel. As a result, extraordinary safety procedures are taken when transporting liquid natural gas.

SENSITIVITY ANALYSIS

The projections of waterborne commerce presented in Chapter III of this appendix were developed using various assumptions as to population growth and economic activity. This section of the report discusses the impact on the projections of varying several of the economic and demographic parameters.

The most fundamental assumption made in the projections included in this report is that the "Series C" OBERS baseline projections of population, income, and manufacturing activity accurately reflect future trends in the Chesapeake Bay Region. Growth in population, income, and output are the driving forces behind increases in demand for the raw materials and products commonly transported by water on the Bay. Since the initiation of the Future Conditions phase of the Chesapeake Bay Study, another set of baseline projections derived from more recent economic and demographic data was prepared and released by the Department of Commerce. As directed by the Water Resources Council (WRC), these projections, called the

"Series E" OBERS projections, must be used by all Federal agencies engaged in water resource planning. The basic differences between the Series C and Series E projections are listed below:

a. The growth of population in the Series E projections will be conditioned by a gradual decline of fertility rates from 2,800 children per 1,000 women (during their lifetime) by the year 2005 projected by Series C to 2,100 children per 1,000 women projected by Series E. This rate represents the "replacement fertility rate."

b. On the basis of the President's 1974 budget message to Congress and observed post-Vietnam War developments, Series E projects the United States military force based in this country to decline to 1.57 million persons by 1975 and to remain constant thereafter. In comparison, the Series C projects a decline to only 2.07 by 1975. As a result of the smaller military establishment, the Series E projections indicate a significantly slower rate of growth in the defense-related manufacturing industries.

c. The hours worked per year are projected to decline at the rate of 0.35 percent per year. The Series C projections used a 0.25 percent rate.

d. The projected rate of increase in product per man-hour in the private economy is lowered from 3.0 percent in Series C to 2.9 percent in Series E.

e. Earnings per worker in the individual industries at the National level are projected to converge toward the all-industry rate more slowly in the Series E projections than in the Series C.

f. Employment/population ratios in the Series E projections will vary between 0.43 and 0.45 as opposed to those used in the Series C projections which were either 0.40 or 0.41. The higher ratios associated with the E Series reflects expected higher participation rates by women.

Table 9-7 presents a comparison of waterborne commerce projections for the major harbors and waterways around Chesapeake Bay based on both Series C and Series E baseline projections. There are significant decreases in the level of traffic for many commodities under Series E assumptions in both Baltimore and Hampton Roads (see Figure 9-59). In Baltimore, this is due primarily to the expected slower rate of growth in defense-related manufacturing. This basic assumption of the Series E projections resulted in an especially significant

TABLE 9-7
COMPARISON OF WATERBORNE COMMERCE PROJECTIONS
BASED ON SERIES C AND SERIES E ASSUMPTIONS
(Thousands of Short Tons)

HARBOR AND COMMODITY	1980 SERIES C	1980 SERIES E	1980 PERCENT CHANGE	1990 SERIES C	1990 SERIES E	1990 PERCENT CHANGE	2000 SERIES C	2000 SERIES E	2000 PERCENT CHANGE	2020 SERIES C	2020 SERIES E	2020 PERCENT CHANGE
Baltimore Harbor												
Residual Fuel	5,970	5,750	-3.7	6,410	5,990	-6.5	6,780	6,130	-9.6	7,480	6,270	-16.2
Gasoline	3,710	3,300	-11.0	5,210	4,480	-14.0	6,510	5,400	-20.0	8,250	6,390	-22.6
Distillate Fuel	2,730	2,360	-13.6	3,570	2,940	-17.7	4,210	3,370	-20.0	5,090	3,740	-26.5
Crude Petroleum	770	940	+22.0	870	1,050	+20.7	950	1,140	+20.0	1,080	1,190	+10.9
Miscellaneous Petroleum Products	1,230	1,130	-8.1	1,580	1,410	-10.8	1,880	1,610	-14.4	2,330	1,820	-21.9
Iron Ore	12,500	9,130	-26.9	13,900	9,110	-34.5	16,300	9,260	-43.2	22,300	9,790	-56.1
Non-Ferrous Ores	1,000	730	-27.0	1,100	720	-34.6	1,300	740	-43.0	1,700	750	-55.9
Gypsum	690	662	-4.1	783	734	-6.3	883	790	-10.5	1,123	898	-20.0
Salt	332	300	-9.6	382	326	-14.7	429	344	-19.8	533	375	-29.6
General Cargo (Foreign)	6,700	6,500	-3.0	9,730	9,200	-5.5	14,100	12,700	-9.9	27,490	22,000	-20.0
Hampton Roads												
Residual Fuel	5,550	5,130	-7.6	5,030	4,540	-9.7	4,480	3,930	-12.3	3,980	3,290	-17.3
Gasoline	1,200	1,070	-10.8	1,540	1,380	-10.4	1,780	1,620	-9.6	2,080	1,820	-12.5

TABLE 9-7 (cont'd)
COMPARISON OF WATERBORNE COMMERCE PROJECTIONS
BASED ON SERIES C AND SERIES E ASSUMPTIONS
(Thousands of Short Tons)

HARBOR AND COMMODITY	1980 SERIES C	1980 SERIES E	1980 PERCENT CHANGE	1990 SERIES C	1990 SERIES E	1990 PERCENT CHANGE	2000 SERIES C	2000 SERIES E	2000 PERCENT CHANGE	2020 SERIES C	2020 SERIES E	2020 PERCENT CHANGE
<u>Hampton Roads</u> (cont'd)												
Distillate Fuel	1,100	910	-17.3	1,470	1,270	-13.6	1,730	1,470	-15.0	2,040	1,690	-17.2
Cement	671	660	-1.6	752	735	-2.3	848	787	-7.2	1,078	881	-18.3
Gypsum	346	340	-1.7	395	386	-2.3	452	419	-7.3	593	482	-18.7
Sand, Gravel, and Crushed Rock	2,130	1,966	-7.7	2,280	2,129	-6.6	2,490	2,227	-10.6	2,860	2,494	-12.8
General Cargo	3,600	3,500	-2.8	5,200	4,920	-5.4	7,500	6,780	-9.6	14,460	11,550	-20.1
<u>Chesapeake and Delaware Canal</u>												
Bulk Oil (Domestic) Westbound	3,580	3,310	-7.5	4,100	3,690	-10.0	4,510	3,940	-12.6	5,130	4,180	-18.5
Eastbound	961	890	-7.4	1,100	990	-10.0	1,210	1,060	-12.4	1,375	1,120	-18.6
General Cargo (Foreign)	4,160	4,140	-.5	4,970	4,920	-1.0	5,960	5,760	-3.4	8,330	7,603	-8.7
<u>James River</u>												
Bulk Oil	2,790	2,750	-1.4	3,810	3,660	-3.9	4,910	4,470	-9.0	6,440	5,443	-14.9
Internal Traffic (Except Bulk Oil)	4,290	4,070	-5.1	4,740	4,500	-5.0	5,320	4,800	-9.8	6,510	5,400	-17.0

TABLE 9-7 (cont'd)
COMPARISON OF WATERBORNE COMMERCE PROJECTIONS
BASED ON SERIES C AND SERIES E ASSUMPTIONS
(Thousands of Short Tons)

	1980			1990			2000			2020		
HARBOR AND COMMODITY	SERIES C	SERIES E	PERCENT CHANGE	SERIES C	SERIES E	PERCENT CHANGE	SERIES C	SERIES E	PERCENT CHANGE	SERIES C	SERIES E	PERCENT CHANGE
Potomac River												
Bulk Oil (Total inbound at Piney Point)	5,970	6,140	+2.8	8,610	9,120	+5.9	10,640	11,130	+4.6	13,280	13,630	+2.6
Bulk Oil (Internal Barge Shipments)	4,670	4,840	+2.8	7,610	8,120	+5.9	9,870	10,360	+4.6	13,080	13,430	+2.6
York River												
Bulk Oil	7,420	7,760	+4.6	8,930	9,960	+11.5	11,030	12,600	+14.0	17,350	19,320	+11.4
Wicomico River												
Bulk Oil	744	705	-5.2	909	826	-9.1	1,030	927	-10.0	1,230	1,041	-15.4
All Other	284	227	-20.0	412	293	-28.9	557	366	-34.3	875	551	-37.0
Nanticoke River												
Bulk Oil	571	547	-4.2	630	536	-14.9	643	516	-19.7	773	634	-18.0
Rappahannock River												
Bulk Oil	430	450	+4.7	760	790	+4.0	1,040	1,050	+1.0	1,430	1,300	-9.1

TABLE 9-7 (cont'd)
COMPARISON OF WATERBORNE COMMERCE PROJECTIONS
BASED ON SERIES C AND SERIES E ASSUMPTIONS
(Thousands of Short Tons)

HARBOR AND COMMODITY	1980 SERIES C	1980 SERIES E	1980 PERCENT CHANGE	1990 SERIES C	1990 SERIES E	1990 PERCENT CHANGE	2000 SERIES C	2000 SERIES E	2000 PERCENT CHANGE	2020 SERIES C	2020 SERIES E	2020 PERCENT CHANGE
Choptank and Tred Avon Rivers												
Bulk Oil	228	169	-26.0	295	201	-31.9	331	217	-34.4	370	236	-36.2
Internal Traffic	275	255	-7.3	410	350	-14.6	540	430	-20.4	820	610	-25.6

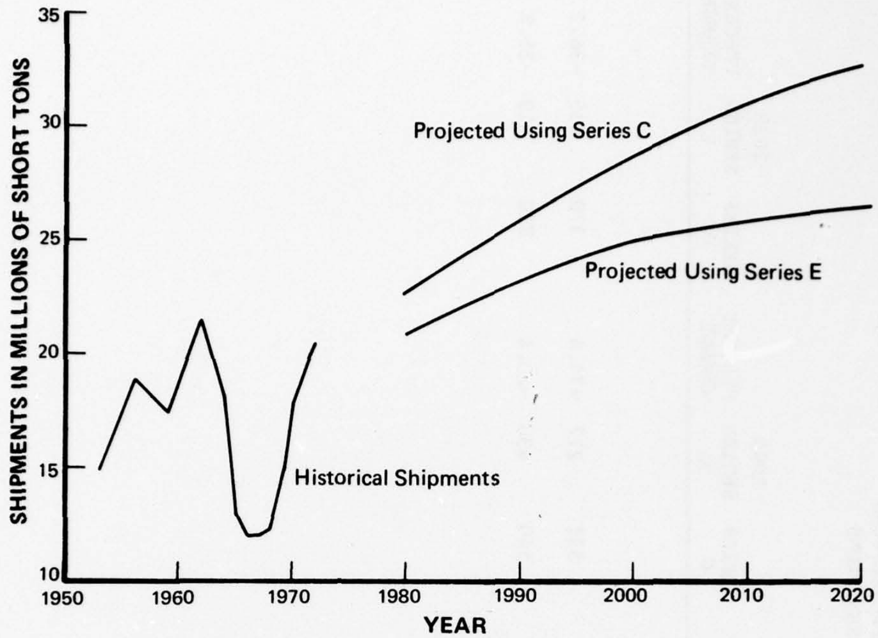


Figure 9-59: BALTIMORE AND HAMPTON ROADS BULK OIL PROJECTIONS—TOTAL RECEIPTS, SERIES C AND SERIES E

impact on the primary metals industry of the area. The iron ore projections in Table 9-7 are derived by reducing the Series C projections by the same percentage as the decline in projected output in the primary metals industry. In Hampton Roads, the decreases in the levels of waterborne commerce are due in large part to an assumed decline in the military forces stationed in the Hampton Roads area. As mentioned previously, the predicted general decline in the United States military establishment may be accomplished by the closing of some bases and the expansion of others rather than the evenly distributed decline assumed. The prediction of the future distribution of armed forces throughout the United States is based on many military, economic, social, and political factors the analysis of which is beyond the scope of this study.

Most of the smaller ports and waterways also showed a reduction in the level of traffic due to the generally lower levels of population and income projected under Series E assumptions. The major exceptions to this generality are the Potomac and Rappahannock Rivers serving the Washington D.C. Economic Area and the York River. Since the Series E and Series C

projections of population and income for the Washington Economic Area are very similar and the Series E projections of refinery output in the Chesapeake Bay Region are slightly higher than Series C, the commerce projections in this economic area increased when the Series E data were used.

A recent decision by the Exxon Corporation may significantly affect the level of petroleum shipments into Chesapeake Bay. Exxon is seriously considering a plan to transport by pipeline virtually all of their "clean products" moving from the Gulf Coast to Baltimore and Hampton Roads. Since the company is presently the major importer of clean products into both the Hampton Roads area and Baltimore, the shift to the pipeline would significantly lower the projections presented in this report. The company will continue to import residual fuel by water into Baltimore and Hampton Roads.

A major assumption affecting the petroleum projections presented in this chapter is the adjustment made to the "unrestrained" demand for these commodities in the future (i.e., unadjusted extension of historical trends, see Metholology Section in Chapter III). Table 9-8 presents the projections for petroleum products without the adjustment. As shown on Table 9-8 the unrestrained projections for both Baltimore and Hampton Roads exceed by nearly three times the base projections developed for the year 2020 in this report. If in fact the unrestrained projections are realized there would be a significant impact on both the need for deeper channels and the number of vessel trips into Chesapeake Bay.

Generally speaking, the results of the sensitivity analysis indicate that the levels of waterborne commerce would decrease significantly if future population trends follow the Series E rather than the Series C projections. However, these reductions in waterborne commerce do not necessarily diminish the present or future need for navigation channels in the Bay and tributaries.

TABLE 9-8
UNRESTRAINED PROJECTIONS OF WATERBORNE BULK OIL FOR SELECTED CHESAPEAKE BAY PORTS
(Millions of Short Tons)

	1980	1990	2000	2010	2020
Baltimore Harbor					
Residual Fuel	6.27	7.51	9.73	13.24	18.34
Gasoline	4.23	7.13	11.68	18.06	27.12
Distillate Fuel	2.92	4.54	6.86	9.98	14.25
Crude Petroleum	0.80	1.00	1.25	1.55	1.95
Miscellaneous	1.37	2.06	3.16	4.70	6.88
Total Unrestrained[1]	15.59	22.24	32.68	47.53	68.54
Total Restrained[2]	14.40	17.60	20.30	22.60	24.20
Hampton Roads					
Residual Fuel	5.76	5.78	6.32	7.78	10.00
Gasoline	1.30	1.97	2.87	3.98	5.42
Distillate Fuel	1.23	1.94	2.78	3.78	5.00
Miscellaneous	0.48	0.48	0.48	0.48	0.48
Total Unrestrained[1]	8.77	10.17	12.45	16.02	20.90
Total Restrained[2]	8.26	8.38	8.29	8.42	8.28
Chesapeake and Delaware Canal					
Bulk Oil (Westbound)	3.85	5.12	7.13	10.04	14.13
Bulk Oil (Eastbound)	1.03	1.37	1.91	2.69	3.79
James River					
Bulk Oil	3.24	5.55	9.59	15.55	24.41
Potomac River					
Bulk Oil (Inbound)	7.10	13.09	22.76	36.84	57.40
Bulk Oil (Internal Outbound)	5.70	11.69	21.36	35.44	56.00

[1] Without the adjustment for petroleum projections explained in Chapter III.
[2] With the adjustment for petroleum projections explained in Chapter III.

TABLE 9-8 (cont'd)
UNRESTRAINED PROJECTIONS OF WATERBORNE BULK OIL
FOR SELECTED CHESAPEAKE BAY PORTS
(Millions of Short Tons)

	1980	1990	2000	2010	2020
Wicomico River					
Bulk Oil	0.79	1.10	1.58	2.26	3.21
Nanticoke River					
Bulk Oil	0.60	0.73	0.96	1.41	2.05
Rappahannock River					
Bulk Oil	0.56	1.26	2.41	4.10	6.57
Choptank and Tred Avon Rivers					
Bulk Oil	0.27	0.41	0.55	0.69	0.84

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CHAPTER IV

MEANS TO SATISFY NEEDS

This chapter describes the broad range alternatives that could be employed to meet the needs presented in Chapter III. The seven general existing or potential waterborne commerce-related needs in the Chesapeake Bay Region identified in Chapters II and III are listed below.

(1) A need to accommodate large bulk vessels expected to dominate the world bulk trade in petroleum, coal, iron ore, and grain in the very near future.

(2) A need for an economically and environmentally acceptable method of dredge material disposal to accommodate the large volumes of dredge material from maintenance and deepening operations during the next 50 years.

(3) A need to alleviate potential congestion problems in port, channel, and anchorage areas.

(4) A need to minimize the potential conflicts between commercial and recreational users of the Bay's waters and beaches.

(5) A need to minimize the erosion damages from waves caused by commercial and military vessels.

(6) A need to minimize accidental spills and eliminate deliberate discharges of wastes from commercial and recreation craft.

(7) A need to provide additional lands to accommodate expanding port facilities.

The most obvious solution to the problem of accommodating larger vessels than existing channels can handle is to deepen the channels to the required depths. This has been the traditional approach taken by port engineers and planners. This approach, however, has recently encountered increasingly serious economic and environmental constraints. First, main channel depths, in both Baltimore and Hampton Roads are approaching physical constraints in the form of existing tunnel crossings. The inner harbor tunnel in Baltimore allows a depth of 50 feet into the inner harbor area. The main channels in Hampton Roads are limited by the Thimble Shoal Channel Tunnel (55 feet) as well as the Hampton Roads Tunnel (65 feet). Although it is theoretically possible to lower tunnels to allow for deeper channel depths, the costs are generally prohibitive. Second, as channel depths increase, the volume of dredge material to be disposed of from both deepening and maintenance operations increases (usually more than proportionately). Finding suitable disposal sites for increasing volumes of dredge material is becoming more and more difficult for both economic and environmental reasons.

There are several alternatives to the deepening of shipping channels to accommodate larger vessels. One alternative is to use restricted draft vessels which are characterized by much wider beams to allow a larger tonnage of cargo to be carried by a vessel of a given draft. Widening the beams of these large vessels requires increased hull strength and additional power to overcome additional wave resistance and added weight. These modifications increase the cost of the vessel significantly. It is the general consensus of opinion of experts in the field that it is feasible to design, construct, and operate restricted draft ships up to certain limits. Nathan in the Deepwater Port Study estimates that a ship of 51,500 d.w.t. is the maximum size which could be built with a fully-loaded draft of 35 feet, and 78,300 d.w.t. is the maximum size with a fully-loaded draft of 40 feet. The "normal" capacity for a vessel with a draft of 35 feet is about 35,000 d.w.t., while the capacity with a 40-foot draft is approximately 50,000 d.w.t. Mitsubishi Industries recently delivered a 153,000 d.w.t. tanker with a 50-foot draft, the "Amoco Trinidad" to Mammoth Bulk Carriers, Ltd. Many experts believe that more extensive draft restriction is beyond present technology because of problems with maneuverability, buoyancy, and stability. The reduced maneuverability and larger dimensions may require channel modifications to assure safe transit and turning radii. In general, however, restricted-draft designs seem to be a possible alternative to the channel deepening problem where the principle commodities are oil and ore. (42)

Another alternative to deepening existing channels is the development of so-called "superports." Under this alternative, one or more superports would be constructed in deep water off the Eastern Coast. Very large vessels, on the order of 300,000 d.w.t. with approximately 75 foot drafts would unload at the deepwater terminal where the cargo (e.g., crude oil, coal, iron ore) would be transported to the mainland by barge or pipeline (i.e., slurry pipelines in the case of dry bulk commodities). The location most often mentioned as a deepwater terminal serving the North Atlantic region is near the mouth of the Delaware Bay. Nathan concluded in the Deepwater Port Study that although an offshore terminal for the handling of crude oil was highly justified economically, the use of such a facility for the major Chesapeake Bay bulk commodities (i.e., coal and iron ore), even when such a facility was combined with an oil facility, was not justified. In fact, calculated benefit-cost ratios were decidedly unfavorable. The different results reflect the combined effects of four factors:(43)

1. Dry bulk transshipment terminals handle much smaller volumes over their entire life cycles.

2. Dry bulk terminals offer smaller average savings in ocean shipping costs per ton because link distances are typically shorter or require large vessels to make circuitous movements (e.g., Panama Canal constraint).

3. Dry bulk terminals incur significantly greater investment, maintenance, and operating costs per ton of cargo handled, because dry bulk storage and handling facilities are more expensive and throughputs are smaller.

4. Dry bulk terminals usually require higher unit transshipment costs because the pipeline alternative is not feasible and vessel transshipment imposes more costly handling.

The Norfolk District of the Corps of Engineers investigated the possibility of a coal slurry system in the Hampton Roads area as an alternative to deepening the channel to 55 feet. The system involves the movement of slurried coal through a pipeline from Hampton Roads to an offshore loading terminal where it would be shipped to other ports. A project of this nature would require the extension of rail service from existing area coal terminals to an onshore storage and preparation plant, the construction of the preparation plant and offshore pipeline assembly, and the installation of an offshore loading facility/mooring buoy. This alternative, however, would cause additional dredging, environmental, and land acquisition problems as well as technical problems concerned with using a slurry system for coking coal. As a result of these problems, as well

as for economic considerations, the channel deepening alternative is superior to the coal slurry system. (44)

Given that a channel should be maintained or deepened, there are numerous alternative ways to dispose of dredge material. (45) The cheapest and easiest method of dredge material disposal is to deposit the material either adjacent to the channel or to barge it to a nearby deep underwater site. In the past there were two major open water disposal sites used in the Upper Bay--Pooles Island Deep and Kent Island. The Pooles Island site was located along the east side of Pooles Island while the Kent Island site was located along the western side of Kent Island between Love Point and the Chesapeake Bay Bridge. Based on recent studies regarding the ultimate fate and environmental impacts of material dumped in these sites, both sites are no longer approved for dredge material disposal. At this time, the future use of a major open water disposal site in the Upper Bay appears unlikely; however, consideration will be given to open water disposal immediately adjacent to channels dependent on environmental and economic concerns.

Open water disposal in the Atlantic Ocean is another possibility for the disposal of dredge material. The major advantage to this alternative is the almost limitless physical capacity of the ocean. This alternative has been used in the past in the Hampton Roads area, but the Baltimore area is too far from the ocean for this type of disposal to be economically feasible. The shortest route to the ocean from Baltimore is through the C & D Canal, a trip of approximately 120 miles to the mouth of the Delaware Bay. With a transportation cost of about $0.06 per cubic yard per mile, it would cost at least $7.2 million to dispose of each one million cubic yards of dredge material. Even if the economics of this alternative were more favorable, the environmental impacts of open water dumping in the Bay would merely be transferred to the ocean site. The Council on Environmental Quality has recommended to the President that ocean disposal of polluted dredge material be phased out as soon as alternatives can be found and implemented.

A variation to open water disposal is the use of an underwater sanitary landfill. Under this alternative, contaminated dredge material would be deposited in open water and then covered over by clean material from areas adjacent to the dumping grounds. The major advantages of this option are that it provides a clean surface for the reinvasion of benthic populations and it separates the contaminated dredge material from the Bay's waters. On the other hand, there would have to be a sacrifice made of the present ecosystem in the vicinity of the area where the clean material is dredged. Although reinvasion would occur, there would be a permanent modification

in the state of the ecosystem because of the change in depths. The environmental impacts of this alternative have not been fully examined. In addition, in order to dredge clean bottom material, Congressional authorization would be required. The economics of such a plan depend on the distance from the disposal site to the area of clean fill material.

Still another alternative method of dredge material disposal is "on land" disposal at land-locked sites including abandoned strip mines in the Appalachians. The major advantage of this option is the potential for converting currently barren, aesthetically unappealing land into productive uses such as grazing land for livestock. There are also, however, significant disadvantages to such an alternative. Transportation to such a site would most probably be by truck, at least part of the trip. This would increase truck traffic along the truck route tremendously. For example, assuming an average truck load of about 5 cubic yards per trip, it would take about 200,000 trips to handle each one million cubic yards of dredge material. In addition, since the material would likely be in a "soupy" condition, some leaking from the trucks can be expected. The dredge material could be placed on land and allowed to drain before being transferred to the final disposal site, but this alternative would increase total costs significantly due to additional handling and storage. It has been proposed that partially dried dredge material already in disposal sites such as Craney Island be transported to land disposal sites while the increased capacity of the disposal site be used for "fresh" dredge material. Since some of the dredge material is highly contaminated, there may be some contamination of both surface water and ground water from these materials. However, the areas of the harbors where the highly contaminated materials are located are generally well defined so that the most undesirable material can be separated and placed in an area where it would be least harmful.

If there are no land-locked sites readily available, a dyked containment structure on water, land, or a combination of the two, can be built. Both the Craney Island site, which has served the Hampton Roads dredge disposal needs for 18 years, and the proposed Hart-Miller Islands site in Baltimore are this type of structure. These specific projects were discussed in more detail in Chapter II. In general, diked disposal sites when properly designed and constructed have several advantages. First, they prevent the unregulated spread of the often syrup-like dredge material (approximately 20 percent solids) into surrounding areas. Second, they are one of the least expensive forms of disposal. Third, the long retention time of the water in the dredge material coupled with the process of sedimentation and filtration within the confinement area will

effectively eliminate the biochemical oxygen demand and any pathogenic bacteria that might be present in the dredge material before the filtrate reaches the Bay's waters. Finally, although landfill composed of dredged material usually provides poor foundation conditions for many years, it will eventually support uses such as ballfields, parking lots, parks, playgrounds, boat launching ramps, and nature trails. (46)

The use of dredged materials for the manufacture of bricks is still another alternative method of disposal. Studies by Yale University and Clemson University indicate that it is technically possible to produce bricks, lightweight aggregate, or related ceramic products from certain types of dredge material. Properties of the dredged material which are important in producing these types of materials include water content, grain size, mineral composition, shell content, and the amount of organic matter present. The quantity of sand in the material must be less than 20 percent, otherwise the strength of the brick is significantly reduced. Because of the low sand content and high percentage of clay, Baltimore Harbor dredge materials, at least, appear to have favorable properties for brick manufacture. This alternative, however, does not appear to be economically feasible at the present time due to problems such as de-watering, the removal of sand, shells, foreign matter, the storage of suitable dredge material and the removal of unsuitable materials, and revisions to standard brick manufacturing processes. There might also be a problem with the disposal of such a large volume of bricks. It would require only about 300,000 cubic yards of dredge material each year to produce enough bricks to equal the present production of the entire State of Maryland. (47) It is highly unlikely that the manufacture of brick will ever, by itself, completely solve the dredge disposal problems of the major Chesapeake Bay harbors. However, this alternative may have an important impact on the disposal of material from smaller projects or maintenance dredging in the major channels if the aforementioned technical problems are solved.

A plan of extracting rare metals from the dredged materials has also been mentioned as an alternative. The major benefit would be the reclamation of economically valuable metals, but the problems are significant. The unused contents must still be disposed of, and since the technology has not been developed, a large capital investment would have to be made for an experimental program. This alternative may be a future solution at best.

Another method used in some projects, to include the Norfolk District of the Corps, has been the use of dredged material for beach nourishment. This may be a practical alternative

for those projects having relatively clean dredged material; however, for those projects involving contaminated dredge material, this option is probably not feasible.

One possible solution to the potential congestion and traffic management problems mentioned in Chapter III was recently recommended by the Fifth Coast Guard District to the Commandant in Washington D. C. (48) After a two year study of the movements of commercial vessels on the Chesapeake Bay, Coast Guard marine safety experts recommended implementation of a comprehensive traffic management system. The plan, which was oriented towards the Port of Baltimore and specifically to the movement of liquid natural gas into the Covepoint terminal now being constructed south of Baltimore, would require the installation of government-operated communications centers at both ends of the Bay. With this network, marine traffic could be controlled in a manner similar to air traffic at a major international airport. This management responsibility has traditionally been delegated to ship pilots and captains. The Coast Guard had not yet made a final decision on the Fifth District's recommendations.

Minimizing potential conflicts between commercial and recreational uses of Chesapeake Bay can best be minimized by a careful selection of dredge material disposal sites, anchorages, and even channels to avoid, whenever possible, popular boating, sailing, fishing, swimming, and nature areas. Lightering sites, especially for petroleum, should be located where possible accidents would have the least effects on recreation areas. Any changes in current, salinity, or temperature changes in the Bay system caused by navigation improvements (e. g., change in channel dimensions, disposal of dredge material) should be carefully analyzed to avoid any disruption of the spawning, nursery, and migration patterns and habitats of fish and wildlife.

As mentioned earlier, erosion caused by the wakes from ships is a serious problem in some areas. The eroding power of a wave is proportional to the square of the wave's height. The height of a ship-induced wave when it hits the shoreline is determined by a number of factors, the most significant being the displacement, speed, and bottom contour of the vessel, the bottom and shoreline contours, and existing turbulence in the surrounding waters. The greater the existing turbulence, the more likely it will be that the waves caused by ships will be dissipated before reaching shore. The simplest corrective action is to lower permitted vessel speeds in areas of high erosion potential. Today's merchant ships, however, are extremely expensive to operate so that delays caused by reduced speed limits, could increase shipping costs considerably.

Another alternative would be to regulate ship traffic so that only those vessels with certain wave-minimizing bottom contours would be permitted in critical areas of the Bay. This alternative would also include a limit on the size of vessels permitted to use these areas. In general, the flatter a vessel's bottom, the lower the wave height produced. A combination of these two alternatives is also a possibility, that is, apply speed limits to those vessels whose bottom contours or size would be likely to produce larger than acceptable waves. It is highly unlikely, however, that the level of erosion damage caused by ship-induced waves in Chesapeake Bay would ever justify such a program. Still another possible solution to the erosion problem, not related to vessels or their operations, would be the provision of either structural or non-structural shoreline protection measures in the critically eroding areas.

Both accidental spills and deliberate discharges of wastes from commerical and recreational craft can create serious water quality problems which can in turn seriously affect fish and wildlife resources. While the complete elimination of accidental spills is not possible there are several actions that can be taken to minimize the number of occurrences. As discussed earlier, a comprehensive traffic management system for the Bay would reduce the potential for a collision or accident that could result in a massive spill. Appropriate Federal, State, and local controls with substantial penalties for non-compliance could also be effective in reducing the number of occurrences. Lastly, response teams can be established at Federal, State, and local levels to minimize damage in the event of an accidental spill.

Regarding the discharge of wastes from both commercial and recreational craft, standards and criteria governing overboard dumping need to be further defined. In response to Public Law 92-500 the provision of holding tanks or other suitable flow through devices on all ships will be very effective in eliminating this problem. Attendant with the inclusion of ship board tanks and devices is the need for shore based facilities that can treat the effluent pumped from ships.

The present and future needs for lands to be used for port-related facilities requires that the appropriate transportation and planning agencies of State and local governments develop zoning and land use plans that will insure the orderly development of the necessary improvements. As part of the development of the appropriate land use plans, consideration will have to be given to the impact on adjacent lands, the need for lands for competing uses such as recreation, and conflicts with natural phenomena to include hurricane flooding and shoreline erosion.

CHAPTER V

REQUIRED FUTURE STUDIES

The existing and future problem areas as they relate to navigation and waterborne commerce all require varying degrees of research and study to include testing on the Chesapeake Bay Hydraulic Model.

One area of particular concern that requires considerable study effort is the effects of changes in bottom topography (i. e., deepening and/or widening of navigation channels and the criteria of dredge spoil disposal areas) on the Bay's current, salinity, and temperature patterns. The proposed deepenings of the channels serving Baltimore and Hampton Roads are of immediate concern. In addition, the effects of the creation of large dredge material disposal sites such as those proposed at Hart and Miller Islands in the Baltimore Harbor area and the vicinity of Buckroe Beach, in the Hampton Roads should be explored. As explained in futher detail in Appendix 16, Hydraulic Model Testing, the Chesapeake Bay Hydraulic Model can be used to determine the changes in various physical parameters that can result from physical laternations of the bottom topography. Given the magnitude and nature of the changes in salinity, current and other patterns assessments as to the impacts on the Bay biota will have to be made in order to determine the ultimate consequences.

More study is also needed on the economic, environmental, and social impacts of the various forms of dredging and dredge material disposal and productive use. This is the type of work now being undertaken at the Office of Dredged Material Research in the Corps of Engineers Waterways Experiment Station at Vicksburg, Mississippi. The following is a list of which should be, and in many cases, are being addressed.

(1) How fast do flora and fauna recover after dredging operations in both the removal and disposal sites?

(2) The fate of dredged material (especially the suspended sediments) in an open water disposal operation.

(3) The physical and chemical changes taking place in the water during dredging operations and the effects on the organisms living in the water. This would include the manner in which contaminants, such as heavy metals become available to the aquatic environment as well as the environmental effects of trace metals associated with suspended particulates (i.e., trace metals not entering solutions).

(4) The best sampling and analysis techniques to predict the probability of adverse effects and regulate operations accordingly.

(5) The environmental and economic feasibility of land disposal. Since the land is man's habitat, aesthetics and land values must enter into consideration, along with problems such as groundwater contamination.

(6) The feasibility of creating artificial marshes and island wildlife habitats.

(7) The location of dyked disposal areas to minimize foundation problems which could cause dyke failures.

(8) The development of techniques to densify (i.e., dewater) deposited sediments in dyked disposal areas to increase capacity.

In addition, more study is needed to determine the feasibility of a Bay-wide management system to control vessel traffic and minimize the potential for damaging accidents especially involving the transport of petroleum products and liquid natural gases. With regard to accidental spills of hazardous materials, additional study as to the ultimate fate and impacts of such things as oil spills is also required. Research should also be directed toward prevention of spills and the best methods for clean-up and recovery following an accidental spill.

The water quality problems associated with the domestic sewage wastes from commercial and recreational craft also require additional study. The magnitude of the problem itself requires further definition to include the identification of berthing and marina areas where the problem is the most severe. Alternative means of holding and treating the wastes should also be analyzed.

There is also a need for more information concerning the proportion of the total erosion problem attributable to ship-induced waves rather than natural causes. This type of information is needed to determine if controls on ship traffic are necessary in critically eroding areas.

Lastly, in areas where existing or proposed port-related facilities are required, consideration must be given to defining the impact on adjacent and/or competing land uses. Also, the development of shoreline facilities requires that studies be conducted to define their susceptibility to hurricane flooding and shoreline erosion.

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FOOTNOTES

1. "Port of Baltimore in Record Boom," The Washington Post, November 24, 1974, pp. D1-D2. This article presented some preliminary findings of an update study prepared in 1969 by Dr. Stanley Hille of the College of Business and Public Administration of the University of Maryland on a report originally entitled "The Economic Impact of the Port of Baltimore on Maryland."

2. Update of a study originally titled "The Contributions of the Ports of Virginia to the Economy of the Commonwealth," by D.C. Darnton and C.O. Meiburg of the Graduate School of Business Administration, University of Virginia, October 1968.

3. Pritchard, Dr. Donald W., "Chemical and Physical Oceanography of the Bay," Proceedings of the Governor's Conference on Chesapeake Bay, September 12-13, 1968, pp. II-50-51.

4. Massmann, William H., "The Significance of an Estuary on the Biology of Aquatic Organisms of the Middle Atlantic Region," A Symposium on the Biological Significance of Estuaries, p. 98.

5. Jones, Hugh, The Present State of Virginia, Chapel Hill: The University of North Carolina Press, 1956.

6. Williams, William A., The Roots of the Modern American Empire (New York: Random House, 1969), p. 196.

7. Boyer, Walter D., World Trade and the United States' Share, Department of Transportation, State of Maryland, August 1971, p. 47.

8. Manual - State of Maryland, 1971 - 1972.

9. Organizations Concerned with the Chesapeake Bay, Wilson, William G.

10. Ibid.

11. Ibid.

12. Ibid.

13. Virginia State Agencies Concerned with Coastal Zone Planning, Management, or Scientific and Engineering Activities, 1973 Edition, Laird, Lynch, Hargis.

14. Ibid.

15. Ibid.

16. This discussion is taken, in large part, from Volume I, 1972 OBERS Projections, September 1972 and April 1974, pp. 5-39.

17. Ibid., pp. 7-8.

18. Rose, David J., "Energy Policy in the U.S.," Scientific American, p. 24.

19. Iron Age, July 15, 1974, p. 13.

20. Nordhaus, William D., "The Allocation of Energy Resources," Yale University, 1974, p. 555.

21. United States Energy: A Summary Review, U.S. Department of Interior, January 1972, p. 12.

22. Based on personnal communications with Baltimore Gas and Electric Company officials.

23. "Sales of Fuel Oil and Kerosene," Mineral Industry Surveys, Bureau of Mines, Department of the Interior, 1953-1972.

24. Personal communications with officials of the Chessie System.

25. "Commodity Studies and Projections," U.S. Deepwater Port Study, Robert R. Nathan Associates, Inc., p. 333.

26. Op. cit., "Commodity Studies and Projections," p. 134.

27. Ibid., pp. 430-431.

28. Ibid., pp. 439-460.

29. These estimates were based on sales data for residual fuel by use for Virginia from Petroleum Facts and Figures, 1971 Edition, and "Shipments of Fuel Oil and Kerosene," Annuals, Mineral Industry Surveys, Bureau of Mines.

30. Based on personal communications with VEPCO officials.

31. Op. cit., "Commodity Studies and Projections," p. 351.

32. Ibid., p. 387.

33. Ibid., p. 333.

34. Calculated from data supplied during personal communications with N & W officials.

35. Based on data supplied by the Baltimore Maritime Exchange, Baltimore, Maryland.

36. Master Planning Study for Port of Baltimore, 1973-1990, Maryland Port Administration, July 1974, pp. 47-50.

37. "Extension of Pier at Piney Point - St. Marys County, Maryland," Draft Environmental Statement, U.S. Army Engineer District, Baltimore, June 1975, pp. 70-71.

38. Ibid., p. 67.

39. "Programming to Meet the Future Container Needs for the Port of Baltimore," Walter C. Boyer, MPA, July 1972, p. 19.

40. Final Environmental Statement, Operation and Maintenance of Baltimore Harbor and Associated Channels, Maryland and Virginia - U.S. Army Engineer District, Baltimore, Maryland, October 1974, p. 5.

41. Craney Island Disposal Area, ... Replacement or Extension, p. 14-17.

42. U.S. Deepwater Port Study, "Summary and Conclusions," Volume I of V, Department of the Army, August 1972, p. v.

43. Ibid., p. 66.

44. Survey Investigation of the Norfolk Harbor and Channels, Virginia, U.S. Army Corps of Engineers, Norfolk District, pp.

45. The discussion is taken in part from the following publications: Final Environmental Statement - Operation and Maintenance of Baltimore Harbor and Associated Channels, Maryland and Virginia; Survey Investigation of the Norfolk Harbors and Channels, Virginia; The Craney Island Disposal Area ... Replacement or Extension; and Final Environmental Statement, Hart and Miller Islands.

46. "Dredged Material Disposal: Effects and Alternatives," Water Spectrum, Vol. 6, No. 3, 1974, p. 33.

47. Final Environmental Statement, Hart and Miller Islands, Item #2, Appendix D, p. 7.

48. "Bay Ship Control by U.S. is Urged," The Baltimore Sun.

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NAVIGATION

GLOSSARY

aerobic:	living, active or occurring only in the presence of oxygen or air.
anadromous:	species of fish, such as shad, which return to fresh water from salt water to spawn.
anerobic:	capable of living or being active in absence of oxygen.
benthic:	the bottom of a water body; organisms which live on the bottom of water bodies.
Coastwise receipts and shipments:	domestic (i. e., non-foreign) traffic receiving a carriage over the ocean or the Gulf of Mexico, (e.g., New Orleans to Baltimore or Puerto Rico to Hampton Roads).
containerization:	shipping method using truck size containers, that are loaded on specially built ships by large cranes.
eco-system:	an entire unit in the total ecology, consisting of a community's living and non-living environment.
effluent:	a liquid, which may or may not be polluted, which flows out of a containing space.
environmental impact statement:	statement concerning the results of man-made disturbances of the physical, chemical, or biological components making up the environment.
erosion:	the removal of soil or rock by the wearing away of land by water and wind.
estuary:	body of water where salt water, through the action of tides and currents, mixes with fresh water flowing from a river.

Fall line:	line that separates the Piedmont Plateau and coastal plain, running roughly through Philadelphia, Baltimore, Washington, and Richmond in the Study Area.
Foreign imports and exports:	traffic between the United States and foreign ports.
Internal receipts and shipments:	traffic between ports or landings wherein the entire movement takes place on inland waterways. Movements on Chesapeake Bay only are considered internal.
photosynthesis:	production of organic substances, especially carbohydrates, from carbon dioxide and water by the action of light on the chlorophyll in green plant cells.
regression analysis:	a technique for estimating the relationship between a dependent variable and one or more independent variables.
salinity:	the concentration of any salt; more technically, sodium chlorinity or halinity.
sedimentation:	the process of depositing any usually finely divided organic and/or mineral matter.
sluice:	a conduit for carrying water at high velocity, or an opening in a structure for passing debris.
substrate:	the layer on which organisms grow, or the substance they live on.
suspended load:	material that is too fine to settle from water at a given physical and/or chemical condition.
T-2 tanker:	a World War II era tanker.
trace metals:	chemical elements appearing in minute quantities in natural systems.
turbidity:	condition of water resulting from suspended matter; water is turbid when the load of suspended material is conspicuous.

Water Resources Development Act: a bill, usually passed by the Congress every two years, authorizing the construction, repair, and preservation of certain public works on rivers and harbors for navigation, flood control, and other purposes, formally called the "Omnibus Bill."

weir: a small dam that diverts the flow of water.

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ATTACHMENT A

DESTINATION OF WATERBORNE COMMERCE ENTERING CHESAPEAKE BAY

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TABLE A-1
DESTINATION OF WATERBORNE COMMERCE ENTERING THE CHESAPEAKE BAY

HARBOR AND COMMODITY	DESTINATION *
BALTIMORE HARBOR	
a. Petroleum Products (including residual fuel, gasoline, distillate fuel, crude petroleum, and miscellaneous petroleum products)	The entire Baltimore Economic Area (See Figure 9-1 on page 5 for delineation of Economic Areas) plus the York Pennsylvania SMSA (which includes Adams and York Counties).
b. Iron Ore	Baltimore Metropolitan Area plus the Great Lakes Area
c. Non-Ferrous Ores	Baltimore Metropolitan Area plus the Great Lakes Area
d. Gypsum	Baltimore Metropolitan Area plus all of the Middle Atlantic States
e. Salt	Baltimore Metropolitan Area
f. General Cargo (Foreign)	Baltimore Metropolitan Area plus the Midwest (including Chicago, Milwaukee, and St. Louis)
HAMPTON ROADS	
a. Petroleum Products (including residual fuel, gasoline, and distillate fuel)	Norfolk-Portsmouth Economic Area, Eastern Shore, Richmond Metropolitan Area
b. Cement	Hampton Roads Area, Eastern Virginia, North Carolina
c. Gypsum	Hampton Roads Area, Eastern Virginia, Eastern North and South Carolinas
d. Sand,Gravel, and Crushed Rock	Norfolk-Portsmouth Economic Area
e. General Cargo	Hampton Roads Area, Southeast U.S., and the Midwest east of Chicago

*The destination area may vary slightly according to commodity type.

TABLE A-1 (cont'd)
DESTINATION OF WATERBORNE COMMERCE ENTERING THE CHESAPEAKE BAY

HARBOR AND COMMODITY	DESTINATION*
JAMES RIVER	
a. Bulk Oil	Richmond Economic Area, Petersburg-Colonial Heights Economic Area
b. Internal Traffic (except bulk oil)	Richmond Economic Area, Hopewell
POTOMAC RIVER	
a. Bulk Oil	Washington Metropolitan Area, Southern Maryland, Delaware River, miscellaneous points on Chesapeake Bay
b. Internal Barge Shipments	Washington Metropolitan Area
YORK RIVER	
a. Bulk Oil	New England, Chesapeake Bay locations, Delaware River locations, West Point (Virginia), U.S. Naval terminal at Cheatham
WICOMICO RIVER	
a. Bulk Oil	Salisbury, Southern Delaware, southern half of the Maryland Eastern Shore, Virginia Eastern Shore
b. Other Commodities	Salisbury Metropolitan Area

TABLE A-1 (cont'd)
DESTINATION OF WATERBORNE COMMERCE ENTERING THE CHESAPEAKE BAY

HARBOR AND COMMODITY	DESTINATION*
NANTICOKE RIVER	
a. Bulk Oil	Vienna, Maryland; Seaford, Delaware; Southern Delaware as far north as Dover, Delaware
RAPPAHANNOCK RIVER	
a. Bulk Oil	Fredericksburg, Virginia Metropolitan Area
CHOPTANK AND TRED AVON RIVERS	
a. Bulk Oil	Cities of Easton, Denton, and Cambridge plus Queen Anne's, Caroline, Talbot, and Dorchester Counties
b. Internal Traffic	Easton and Cambridge (two seafood producing firms in Cambridge distribute their products to much of the Eastern U.S.)

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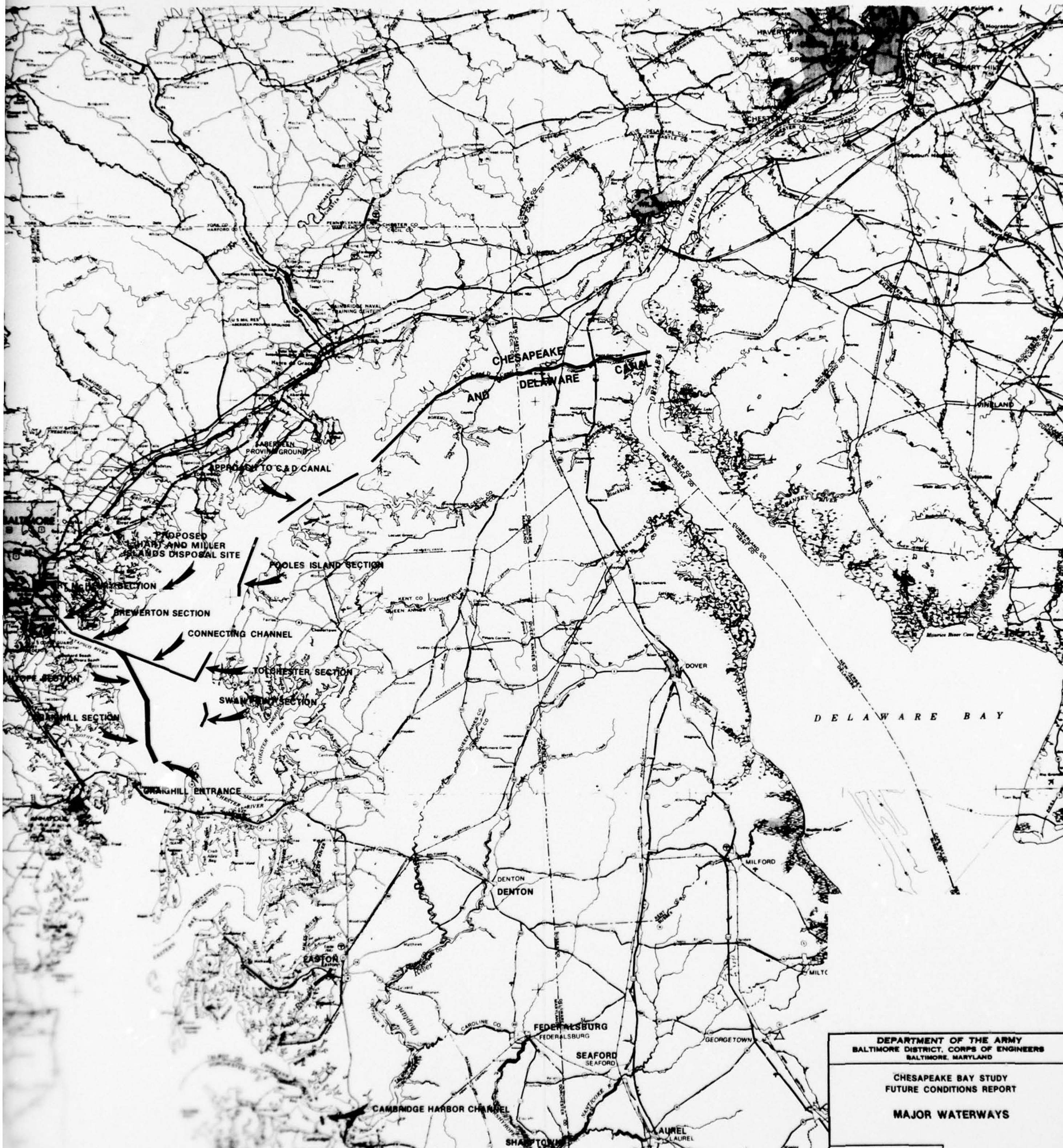
CORPS OF ENGINEERS



DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

CHESAPEAKE BAY STUDY
FUTURE CONDITIONS REPORT

MAJOR WATERWAYS

UPPER BAY

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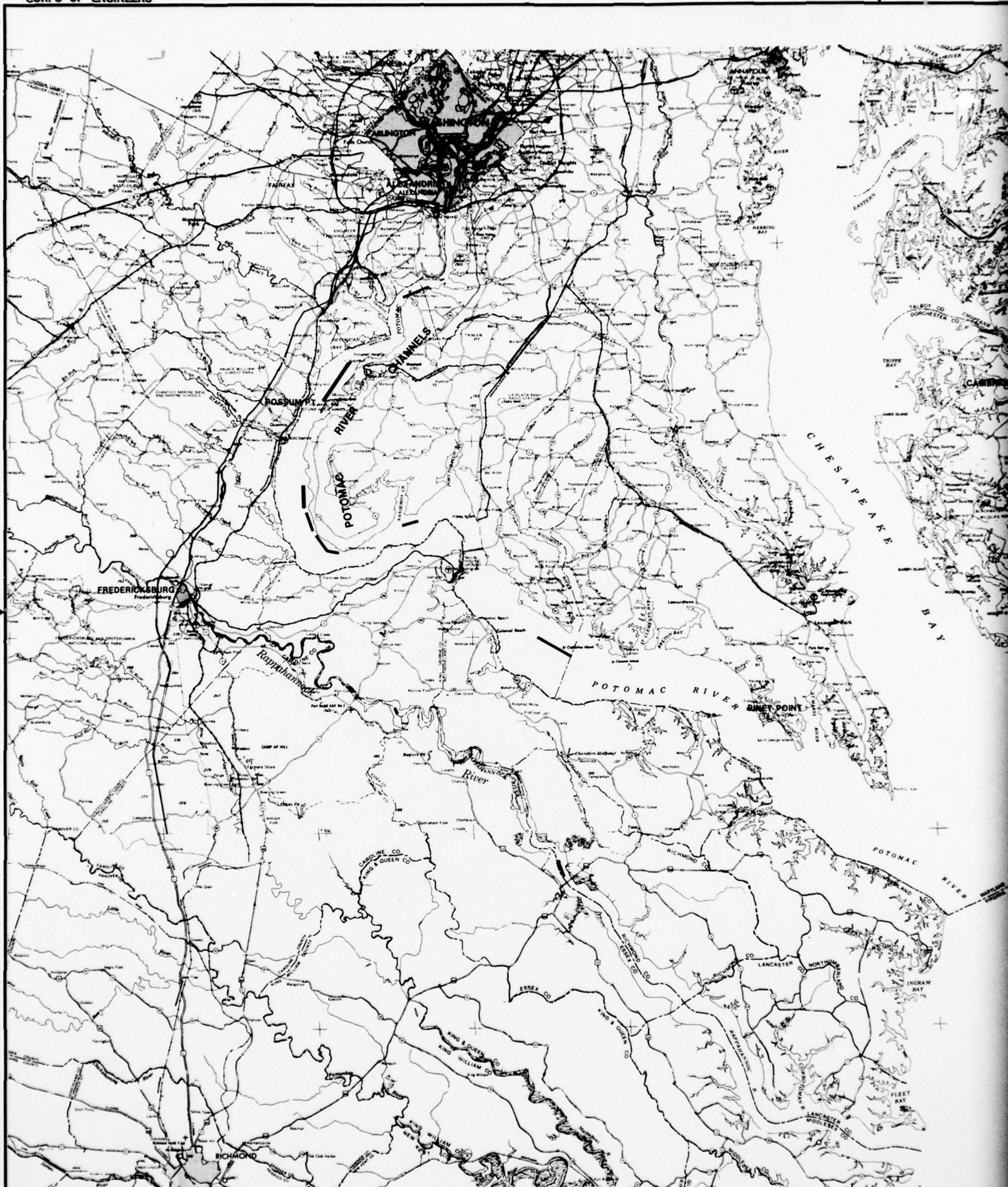

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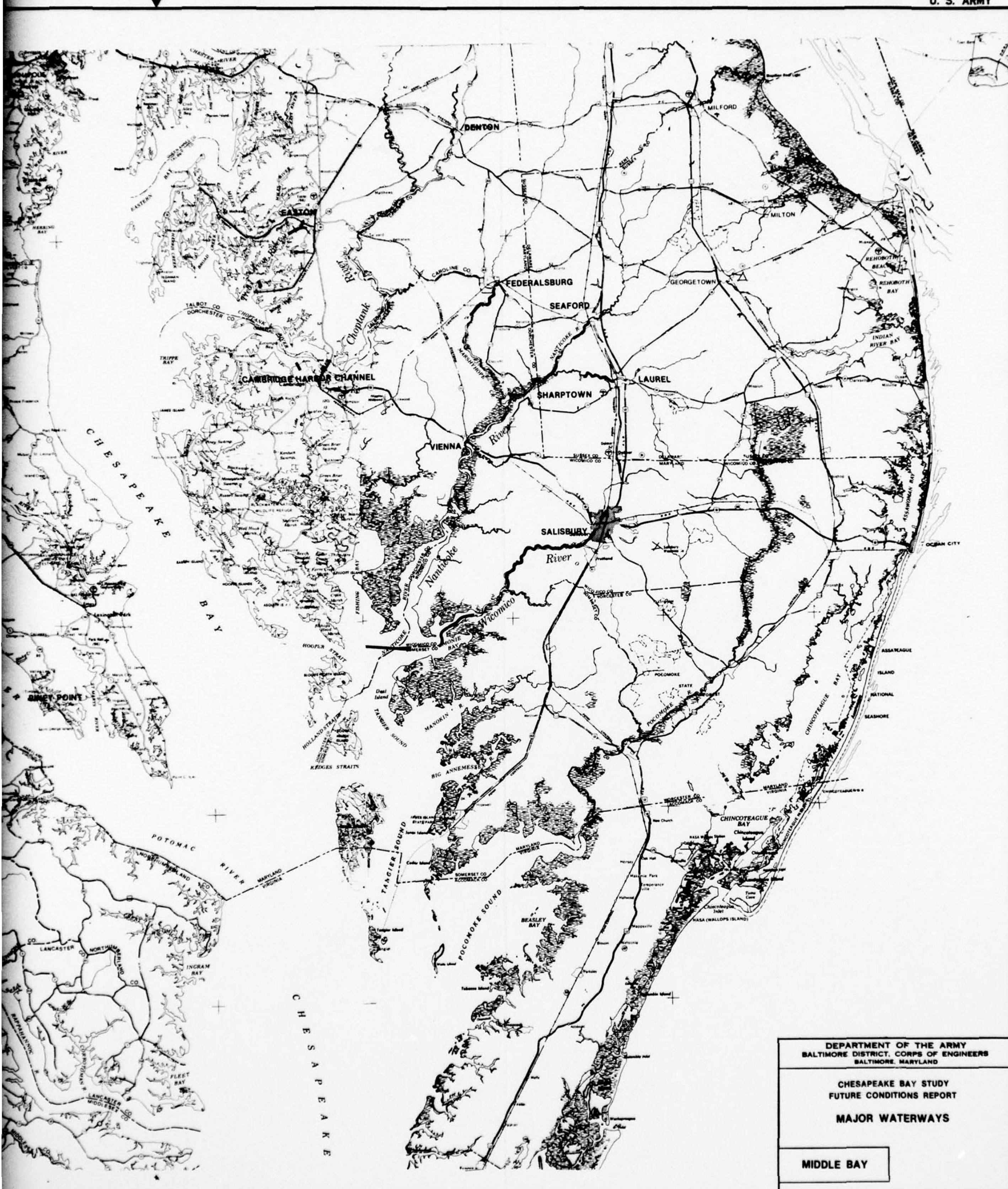

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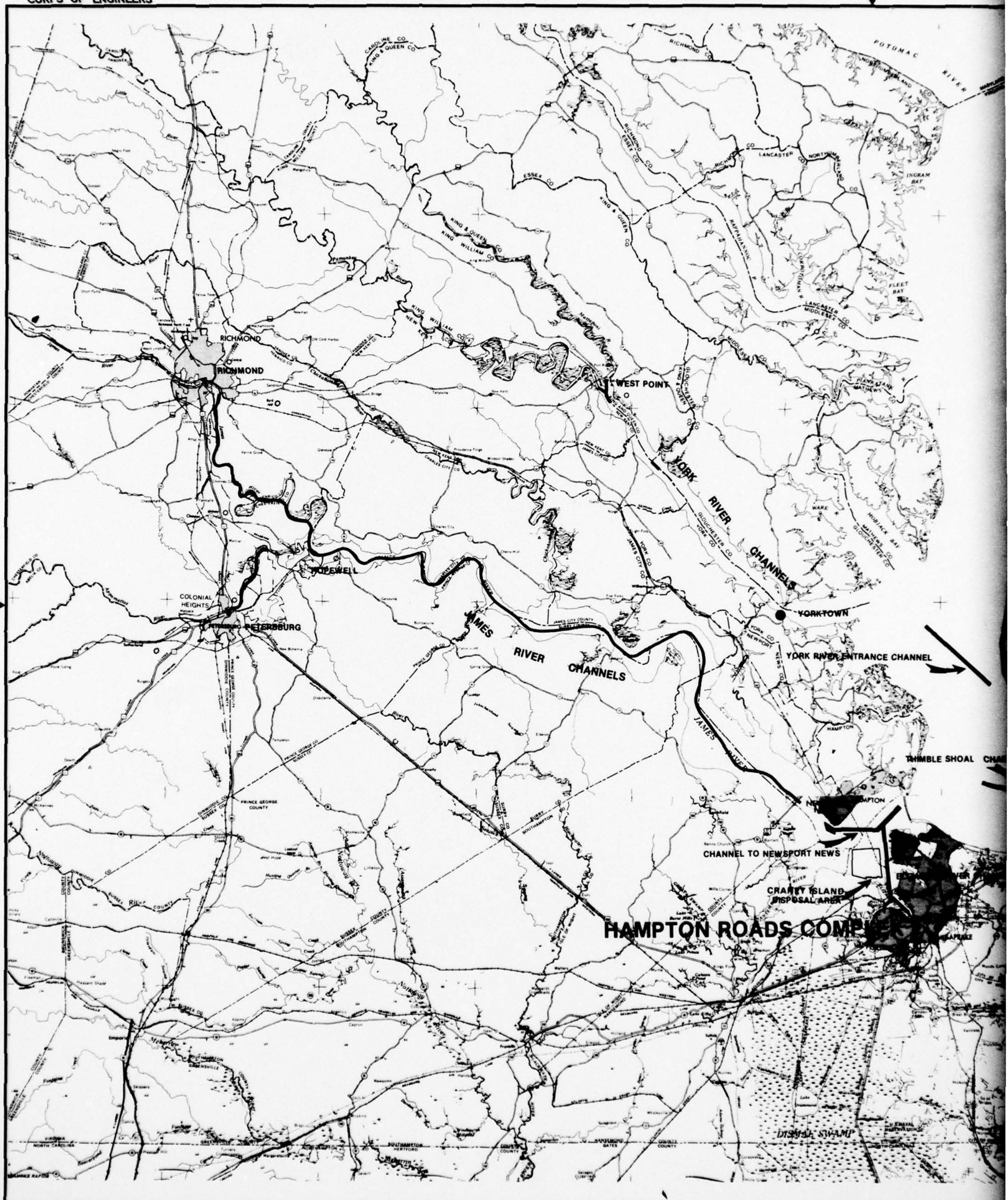
CHESAPEAKE BAY STUDY
FUTURE CONDITIONS REPORT

MAJOR WATERWAYS

MIDDLE BAY

CORPS OF ENGINEERS



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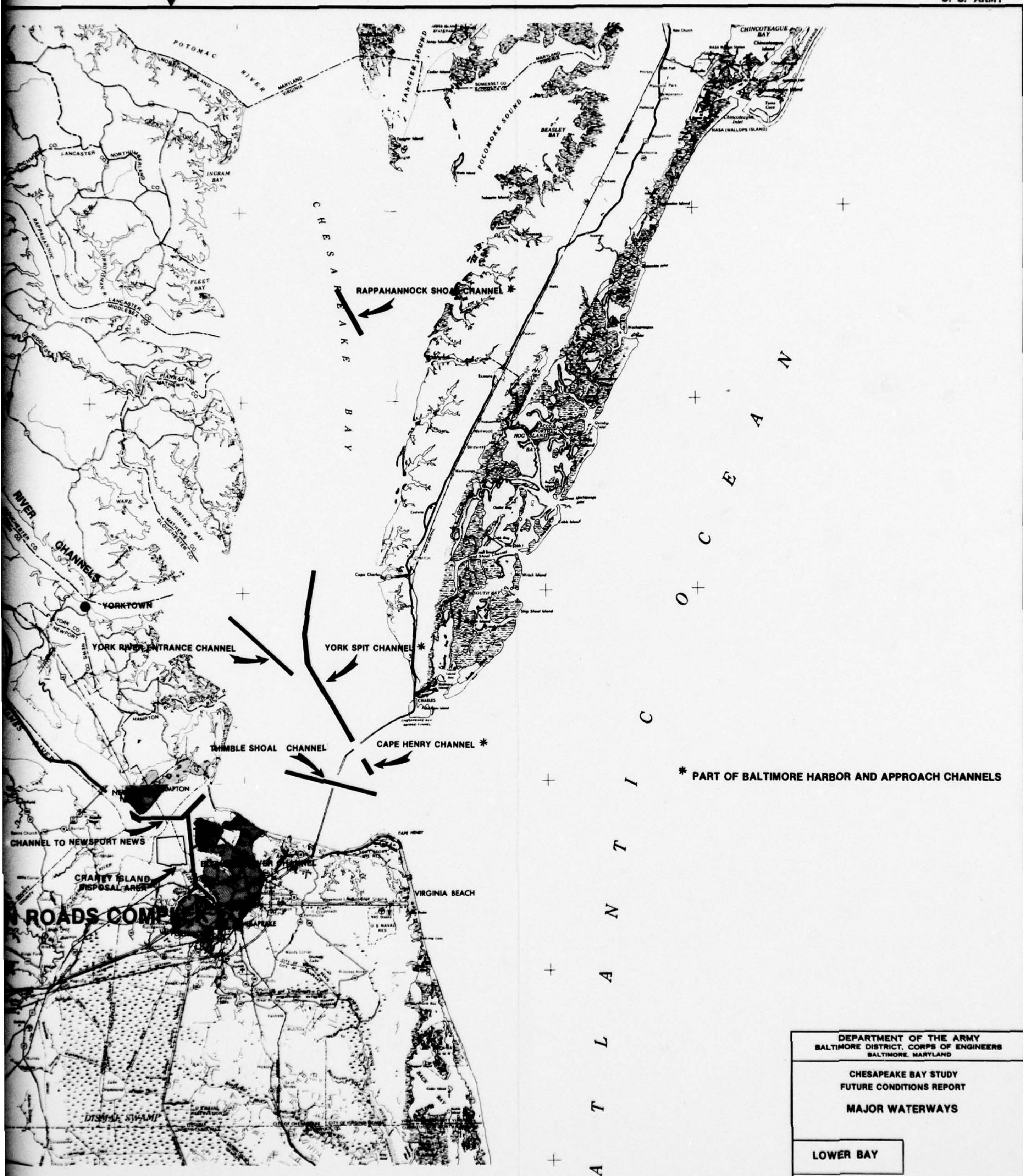

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

CHESAPEAKE BAY STUDY
FUTURE CONDITIONS REPORT

MAJOR WATERWAYS

LOWER BAY

PLATE 9-3

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CHESAPEAKE BAY
FUTURE CONDITIONS REPORT
APPENDIX 10

FLOOD CONTROL

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CHAPTER I
THE STUDY AND THE REPORT

The Chesapeake Bay Study evolved through the need for a complete and comprehensive investigation of the use and control of the water resources of the Bay Area. In the first phase of the Study, the existing physical, biological, economic, social, and environmental conditions and problem areas were identified and presented in the *Existing Conditions Report*. The *Future Conditions Report*, of which this appendix is a part, presents the findings of the second or projections phase of the Study. Included as part of the second phase are the projections of future water resource needs and problem areas, identification of general means that might best be used to satisfy those needs, and recommendations for future studies and hydraulic model testing. The results of this phase of the Study and this report constitute the next step toward the goal of developing a comprehensive water resource management program for Chesapeake Bay.

Chesapeake Bay is a vast natural resource. Along with its tributaries, the Bay provides a natural transportation network on which the economic development of the Region has been based, a wide variety of water-oriented recreational opportunities, a home for numerous fish and wildlife, a source of water supply for both municipalities and industries, and the site for final disposal of our waste products. All of the resources provided by the Bay interact with each other in forming the Chesapeake Bay Ecosystem. Unfortunately, problems often arise when man's intended use of one resource conflicts with either the natural environment or man's use of another resource.

Because of the many resources that the Bay has to offer, extensive development has occurred along its shoreline. Because of the transportation network offered by the Bay, cities developed along many of the sub-estuaries and shipping and handling facilities and related industry were located along the shoreline. The increased demand for waterfront home sites in recent years has also accounted for widespread development. Conflicts arise when shoreline development occurs in areas that are subject to tidal flooding.

Appendix 10

The subject of this particular volume is tidal flooding and as such will focuses on the conflict between man's use and development of the (cont on p 2)

shoreline and the natural process of flooding. This ~~volume,~~ appendix identifies both existing and projected future flood prone areas and the various measures that can be used to prevent or reduce flood damages. Those studies required to develop a comprehensive flood control program for Chesapeake Bay are also identified. (cont p. 1 App 11)

AUTHORITY

The authority for the Chesapeake Bay Study and the construction of the hydraulic model is contained in Section 312 of the River and Harbor Act of 1965, adopted 27 October 1965, which reads as follows:

> (a) The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a complete investigation and study of water utilization and control of the Chesapeake Bay Basin, including the waters of the Baltimore Harbor and including, but not limited to, the following: navigation, fisheries, flood control, control of noxious weeds, water pollution, water quality control, beach erosion, and recreation. In order to carry out the purposes of this section, the Secretary, acting through the Chief of Engineers, shall construct, operate, and maintain in the State of Maryland a hydraulic model of the Chesapeake Bay Basin and associated technical center. Such model and center may be utilized, subject to such terms and conditions as the Secretary deems necessary, by any department, agency, or instrumentality of the Federal Government or of the States of Maryland, Virginia, and Pennsylvania, in connection with any research, investigation, or study being carried on by them of any aspects of the Chesapeake Bay Basin. The study authorized by this section shall be given priority.
>
> (b) There is authorized to be appropriated not to exceed $6,000,000 to carry out this section.

An additional appropriation for the study was provided in Section 3 of the River Basin Monetary Authorization Act of 1970, adopted 19 June 1970, which reads as follows:

> In addition to the previous authorization, the completion of the Chesapeake Bay Basin Comprehensive Study, Maryland,

Virginia, and Pennsylvania, authorized by the River and Harbor Act of 1965 is hereby authorized at an estimated cost of $9,000,000.

As a result of Tropical Storm Agnes, which caused extensive damage in Chesapeake Bay, Public Law 92-607, the Supplemental Appropriation Act of 1973, signed by the President on 31 December 1972, included $275,000 for additional studies of the impact of the storm on Chesapeake Bay.

PURPOSE

Previously, measures taken to utilize and control the water and land resources of the Chesapeake Bay Basin have generally been oriented toward solving individual problems. The Chesapeake Bay Study provides a comprehensive study of the entire Bay Area in order that the most beneficial use be made of the water-related resources. The major objectives of the Study are to:

a. Assess the existing physical, chemical, biological, economic, and environmental conditions of Chesapeake Bay and its water resources.

b. Project the future water resources needs of Chesapeake Bay to the year 2020.

c. Formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

The *Chesapeake Bay Existing Conditions Report*, published in 1973, met the first objective of the Study by presenting a detailed inventory of the Chesapeake Bay and its water resources. Divided into a summary and four appendixes, the report presented an overview of the Bay Area and the economy; a survey of the Bay's land resources and its use; and a description of the Bay's life forms and hydrodynamics.

The purpose of the *Future Conditions Report* is to provide a format for presenting the findings of the Chesapeake Bay Study. Satisfying the second objective of the Study, the report describes the present use of the resource, presents the demands to be placed on the resource to the year 2020, assesses the ability of the resource to meet future demands, and identifies additional studies required to develop a management plan for Chesapeake Bay.

SCOPE

The scope of the Chesapeake Bay Study and *Future Conditions Report* includes the multi-disciplinary fields of engineering and the social, physical, and biological sciences. The Study is being coordinated with all Federal, State, and local agencies having an interest in Chesapeake Bay. Each resource category presented in the *Future Conditions Report* projects demands and potential problem areas to the year 2020. All conclusions are based on historical information supplied by the preparing agencies having expertise in that field. In addition, the basic assumptions and methodologies are quantified for accuracy in the sensitivity section. Only general means to satisfy the projected resource needs are presented, as specific recommendations are beyond the scope of this report.

As shown on Figure 10-1, the geographical area considered in the overall study encompasses those counties or Standard Metropolitan Statistical Areas (SMSA) which touch or have a major influence on the Estuary. For purposes of projecting the future demands on the resources of the Bay, economic and demographic projections were made for all subregions and SMSA's within the Study Area. Regarding tidal flooding, however, the actual Study Area included only that shoreline area along the Bay and tributaries which is influenced by tidal action.

SUPPORTING STUDIES

This appendix was prepared and coordinated by the Baltimore District, Corps of Engineers. Much of the information included in this report was taken from other sources. The initial data base for this particular volume, as well as all other volumes of this report, was presented in the *Chesapeake Bay Existing Conditions Report*. Other studies that provided a major input to this appendix include hurricane surveys that have been prepared by the Baltimore and Norfolk Districts of the Corps of Engineers for Washington D.C.; Baltimore; Norfolk; and the tidewater portions of the Patuxent, Potomac, and Rappahannock Rivers. Numerous flood plain information reports prepared by the Corps of Engineers were also very helpful in the preparation of this appendix. All sources of data used in this appendix are referenced in the Bibliography.

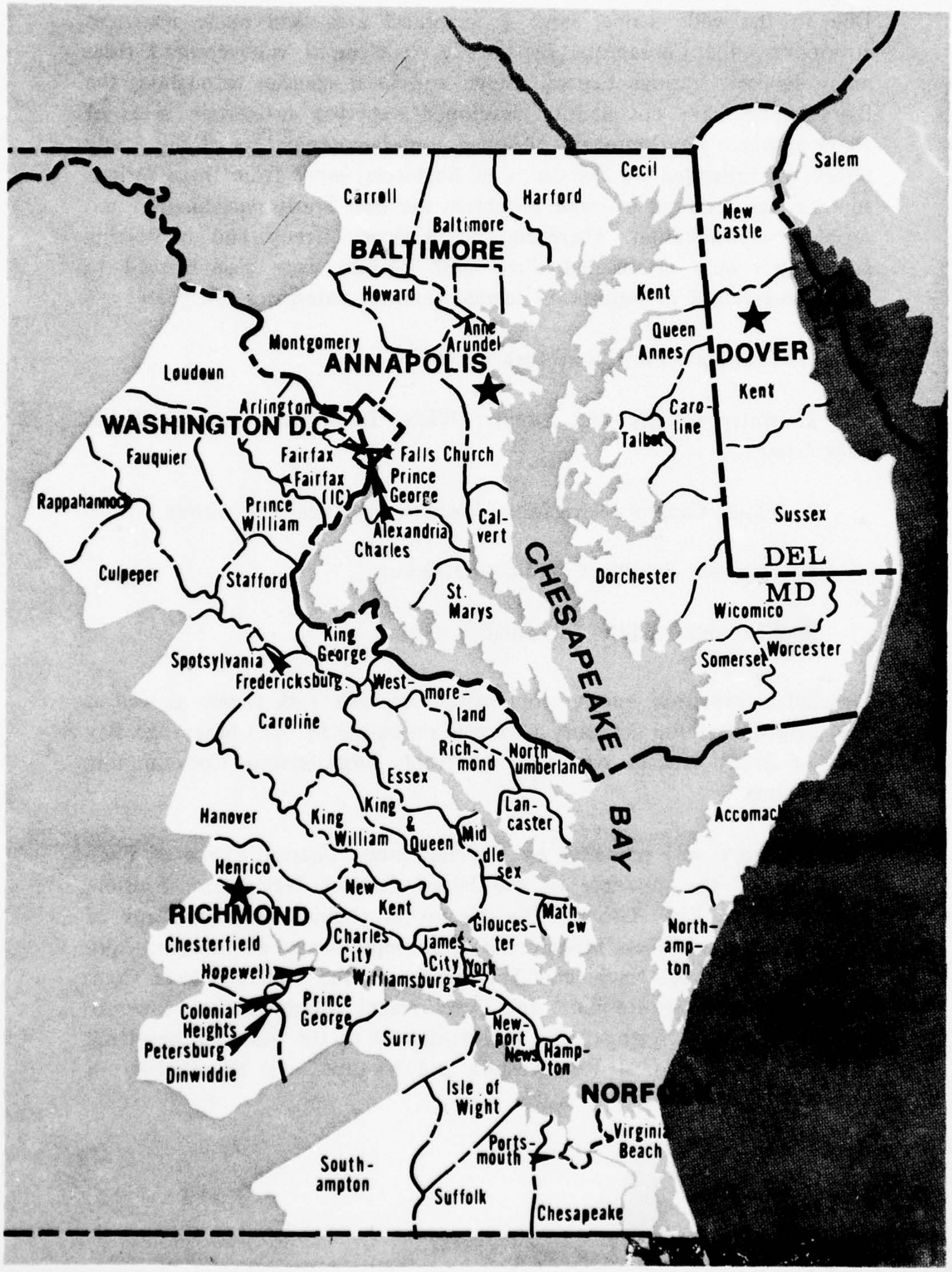

FIGURE 10-1 CHESAPEAKE BAY ESTUARY AREA

STUDY PARTICIPATION AND COORDINATION

Due to the wide scope, large geographical area, and many resources covered by the Chesapeake Bay Study, data input was required from many sources. Various Federal, State, and local agencies throughout the Bay Region have customarily developed expertise in certain areas of water resource development. Although overall coordination of the Study effort was provided by the Corps of Engineers, input from these various sources was required in order to obtain the best Study coordination and problem identification. Therefore, an Advisory Group and a Steering Committee were established. Five Task Groups were also formed to guide preparation of reports on related resource categories. They are:

1. Economic Projection Task Group

2. Water Quality and Supply, Waste Treatment, Noxious Weeds Task Group

3. Flood Control, Navigation, Erosion, Fisheries Task Group

4. Fish and Wildlife Coordination Group

5. Fish and Wildlife Coordination Group

Detailed information on the composition of each Task Group as well as the members of the Advisory Group is presented in the Chesapeake Bay Plan of Study and in Appendix 1, "Study Organization, Coordination, and History."

This appendix was prepared by the Baltimore District, Corps of Engineers, under the guidance of the Flood Control, Navigation, Erosion, and Fisheries Task Group. The Group is chaired by the Corps of Engineers and members include the U.S. Departments of Interior, Agriculture, Commerce, Navy, and Transportation; the Federal Power Commission; the Energy Research and Development Administration; Environmental Protection Agency; and representatives of the State of Maryland, the Commonwealths of Pennsylvania and Virginia, and the District of Columbia.

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CHAPTER II

TIDAL FLOODING IN CHESAPEAKE BAY

Since man first developed along the shoreline of Chesapeake Bay, he has been subject to periodic tidal flooding which has resulted in loss of life, immeasurable human suffering, and millions of dollars of property damage. This chapter includes a survey of the causes of tidal flooding, the tidal floods of the past and their effects on man and the estuarine environment. Based on an analysis of past flooding and the current development within the flood plain a listing of those communities which are prone to tidal flooding is also provided.

DESCRIPTION OF REGION

Chesapeake Bay is one of the largest estuaries in the United States having a surface area of about 4,400 square miles and a length of nearly 200 miles. The width of the Bay varies from 4 miles to about 30 miles near the Maryland-Virginia boundary. The Bay receives freshwater from a drainage area of 64,160 square miles with the Susquehanna, Potomac, Rappahannock, York, and James Rivers providing approximately 90 percent of the total freshwater flow into the Bay. The shoreline of the Bay and its many tidal tributaries is approximately 7,300 miles. Much of this shoreline is vulnerable to tidal flooding.

The Bay is located in a humid continental zone characterized by plentiful sunshine, abundant precipitation, and a long frost-free season. The average temperature for the Study Area as a whole is 57 degrees Fahrenheit and ranges from an average monthly low of 37 degrees in January to an average monthly high of 78 degrees in July. The average annual precipitation is approximately 44 inches. Storms affecting the Region are generally one of three types: (a) large area extratropical storms or "lows" that generally originate in the Rocky Mountains, Pacific Northwest, or the Gulf Coast, and move eastward across the United States; (b) tropical storms or hurricanes that originate in the South Atlantic or Caribbean and move northward through the eastern part of the United States; and (c) local thunderstorms that usually affect a relatively small area.

The Bay lies entirely within the Coastal Plain, a geologic province characterized by poorly consolidated marine and fluvial sediments. The

topography of the area varies from the flat, low-lying almost featureless terrain of the Eastern Shore to the more rolling hills of the Western Shore. Large portions of the shoreline area, particularly the lower Eastern Shore, are very low lying with elevations less than ten feet above mean sea level.

Development in the Bay Region has generally occurred along the Bay's tidal tributaries which provided natural transportation routes for waterborne commerce. The largest metropolitan areas are located on the Western Shore and include Baltimore, Maryland; Washington, D.C.; Richmond, Virginia; and Norfolk-Portsmouth, Virginia. These four metropolitan areas contained approximately 80 percent of the nearly 8 million who lived in the Bay Region in 1970. As indicated above, a large part of the past and present development in the Region is centered around port-related activities which by their very nature are located in areas that may be subject to tidal flooding.

The Chesapeake Bay Region is one of the most important seafood harvesting and processing areas in the Nation with the waters of the estuary yielding millions of pounds of finfish and shellfish annually. Most of the seafood processing and packaging firms in the area are located along the waterfront and as such may suffer damage from tidal flooding.

The recreational and aesthetic pleasures offered by the Bay lead thousands of people to her shores annually. Over the years many people have constructed either permanent or second homes along the shoreline in order to enjoy recreation pursuits on a more regular basis. Unfortunately, many of these homes are located in the tidal flood plain. Commercial recreation developments to include numerous marinas and charter boat services are also located along the shoreline in areas subject to tidal flooding.

TIDAL FLOODING

Generally, serious tidal flooding in the Chesapeake Bay Region is caused by either hurricanes or "northeasters." "Hurricane" is a term used to describe tropical cyclones that originate near but not directly over the equator. Tropical cyclones form over all the tropical oceans except the South Atlantic and are known as hurricanes in the South Pacific, eastern North Pacific, southern Indian and North Atlantic Oceans. In other locations, they are known as typhoons or cyclones. The term "cyclone"

has come into universal use as a term to designate all classes of storms rotating about centers of relatively low atmospheric pressure.

Hurricanes usually develop in "the doldrums," the belt of equatorial calms lying between the two tradewind systems. This area of calm air exists between the prevailing northeasterly winds north of the equator and the southwesterly winds south of the equator. The two wind systems do not precisely balance each other and the belt of calms is always located north of the equator with its southern extent depending upon the advance and extent of the tradewinds. When the doldrums are within 6° of the equator, cyclones seldom form. In this area the deflective effect of the earth's rotation is small, becoming zero at the equator. Only when the doldrums are located north of 6° north latitude is the effect of the earth's rotation sufficient to initiate the counter-clockwise rotation associated with hurricanes in the northern hemisphere. The North Atlantic belt of doldrums is farthest north during the months of August and September and at that time the deflective effect of the earth's rotation is the greatest. Near the equator, this effect is small and there is no evidence of any West Indian hurricane originating south of about 6° north latitude in the Atlantic Ocean. Hurricanes originate when a large mass of calm air becomes warm or moist as compared to its surroundings and upward motion results on a large scale. If this condition occurs at a sufficient distance from the equator for the deflective effective of the earth's rotation to be operative, a cyclone is formed. Hurricanes which reach the Middle Atlantic States are formed either in the Atlantic Ocean in the Cape Verde Region or the western Caribbean Sea and move westerly and northwesterly, in most cases recurving to a northerly and northeasterly direction in the vicinity of the East Coast of the United States.

In all hurricanes that originate in the North Atlantic or the Caribbean Sea, the rotation of the winds is in a counterclockwise direction due to the effect of the earth's rotation at the origin of the storm. The forward movement of the storm combined with its counterclockwise rotation causes the maximum wind velocities to occur in the right semi-circle of the hurricane. Each hurricane contains an "eye" or a calm center with a diameter usually of approximately 14 miles, although there are wide variations in individual cases. The highest winds of the storm encompass the eye of the hurricane. These winds diminish as the distance from the eye increases. The diameter of the hurricane in some cases is not more than 50 to 75 miles, but in the majority, the

diameter is greater and in many instances has exceeded 500 miles. Tropical storms are generally not classified as hurricanes until they attain wind velocities of 75 m.p.h., but storms of lesser intensity do, in some cases, cause more damage than more intense storms because of their forward speed and path.

At any given point in the path of a hurricane the barometric pressure decreases as the storm approaches and reaches a low value as the eye of the storm passes. The low pressure in the eye of the storm is maintained by the centrifugal force of the rotating winds which keep air from entering the low pressure area of the eye. As the hurricane moves overland the topographic features tend to reduce the wind intensity, and the low pressure center starts to fill with air reducing the pressure differential and eventually dissipating the hurricane.

Most hurricanes that have affected the Eastern Coast of the United States have formed either near the Cape Verde Islands or in the western Caribbean Sea. Hurricanes originating near the Cape Verde Islands move westward for a number of days with a forward speed of about 10 miles an hour, then usually turn north, frequently crossing the West Indies and sometimes striking the Eastern Coast of the United States. Hurricanes originating in the Caribbean generally move northward, striking Cuba, the Gulf Coast or the Eastern Coast of the United States. After recurving, the forward speed usually increases to 25 to 30 miles an hour, and occasionally to 60 miles an hour. Cape Verde hurricanes commonly recurve (that is, turn northward, then east of north) after reaching the mid-Atlantic. Hurricanes that affect the Bay Area most severely usually arrive from the south-southwest after recurving east of Florida and after skirting the coastline. These hurricanes usually occur during the period from the first of August through the middle of October.

Heavy rainfall usually accompanies a hurricane. The heaviest rainfall almost always precedes the passing of the center of the storm. Hurricanes are also accompanied by thunder and lightning. Frequent and almost continuous lightning has been observed in the destructive wind circle of many tropical storms. Thunderstorms are most frequently observed after the passing of the hurricane and are sometimes considered as a sign that the hurricane will soon pass.

Winds of hurricane intensity blowing over long fetches of open seas

generate high waves. In deep water the wave height is dependent upon the wind speed, the length of fetch affected by the wind, and the duration of the wind over the fetch. As a deep water wave approaches the sloping bottom adjacent to a shore line, the wave increases in height until it breaks. Waves generated at sea often reach the coast in advance of the storm. Waves that reach the coast can run up on a shelving beach or overtop structures well above the wave height.

As a hurricane progresses over the open water of the ocean, a tidal surge is built up, not only by the force of the wind and the forward movement of the storm wind field, but also by differences in atmospheric pressure accompanying the storm. This surge is further increased as the storm approaches land over a gradually shoaling ocean bed and is influenced considerably by the contours of the coastline. An additional rise occurs when the tidal surge invades a bay or estuary and hurricane winds drive waters to higher levels in the shallow waters. Tidal surges are greater, and the tidal flooding more severe in coastal communities which lie to the right of the storm path due to the counterclockwise spiraling of the hurricane winds and the forward movement of the storm. The actual height reached by a hurricane tidal surge and the consequent damages incurred depend on many factors to include shoreline configuration, bottom slope, difference in atmospheric pressure and wind speed.

"Northeaster" is a term given to a cyclone which almost invariably has developed near the Atlantic Coast and intensified to the extent that it produces high wind, waves, tides, and rainfall along the coast. These storms usually develop along the boundary between warm and cold air masses, starting as a wave of instability and developing into a storm center. These storms develop so rapidly that an apparently harmless weather situation may be transformed into a severe storm in as little as 6 hours. Such storms have frequently caused wind and water damage along the Atlantic Seaboard.

The greatest number of northeasters occur in the winter months when the greatest temperature contrasts occur between the continental and maritime air masses. Statistics indicate that the east coast of the United States has a comparatively high incidence of formation of cyclones with the coastal area of the Middle Atlantic States , especially from the Virginia Capes south to Cape Hatteras, being one of the centers of highest frequency.

Newly developed storms in the Atlantic Coastal Region have moved in

all directions with a variety of forward speeds. Analysis of data on the movement of cyclones indicates the most frequent 24-hour movement of storms in the period 1929-1939 was toward 55° (east of north) at a speed of about 27 miles per hour.

The northeaster differs from the hurricane in many ways, the most important difference being the lesser degree of symmetry. Whereas the hurricane is rather symmetrical, the northeaster is asymmetrical with respect to temperature, wind circulation, pressure distribution, water vapor content, cloudiness and precipitation. Wind speeds are not as great and central pressures are not as low as in a hurricane, but the strongest winds cover a considerably greater area. The asymmetry of northeasters combined with the broader areas of strong winds, and the fact that the northeaster may stagnate, all contribute to the occurrence of prolonged periods of onshore winds which generate damaging waves.

In general, by the time the storm centers of the above storms reach the more populous Western Shore of the Bay area the intensity of the storms are somewhat diminished by passing overland and sustained winds of hurricane velocity are relatively rare. However, the tidal surges generated at the mouth of the Bay are transmitted up the Bay and its tributaries with resultant high levels of tidal flooding. Waves formed by the high winds over the long fetches of the Bay are superimposed on the high tides and have very destructive effects on both the shoreline itself and shoreline structures.

HISTORY OF TIDAL FLOODING

In the course of recorded history, the Bay Region has experienced on the order of 100 storms that have caused damaging tidal flooding. The earliest known account of a great storm in this area appeared in Arthur P. Middleton's *Tobacco Coast*. This storm was the great "Hurry-Cane" of August 1667 which caused unprecedented floods in the upper waters of the rivers and raised the water even in the lower estuaries to a destructive height. Fields were inundated, crops were torn to shreds, houses and barns were carried away, and even the largest vessels were washed up on the beach. J. Thomas Scharf, in his *History of Baltimore City and County*, states that the most destructive storm of later times occurred in July 1837. The water rose twenty feet above its bed and many sections of the city were flooded by more than five feet of water.

The accounts of most of the storms that occurred prior to 1900 are very brief and are usually found only in early newspaper articles and private journals. The elevation and the area inundated by these early tidal floods was seldom documented and it was not until the early part of the 20th century that a program to maintain continuous records of tidal elevations was initiated. The damages and loss of life suffered during these early floods is also not well documented. Fortunately, the level of development in the flood plain was limited and the damages were not that large when compared with a recurrence of the same flood under today's conditions. A listing of the more severe storms that occurred prior to 1900 are included in Table 10-1.

TABLE 10-1
CHESAPEAKE BAY STORMS PRIOR TO 1900

August 1677	March 1846
October 1749	August 1879
September 1769	April 1889
September 1821	September 1896
October 1825	August 1899
July 1837	

The more recent storms or those occurring since 1900 are much better documented than the earlier storms and provide the basis for an evaluation of the depth of flooding and the damages that may be expected from a major tidal flood. Table 10-2 provides a comparison of the recorded tidal elevations at several locations for the most severe floods that have occurred in this century. It should be noted that the relative severity of the storms shown on Table 10-2 varies at various points around the Bay, i.e., the second highest tides in Baltimore and Norfolk were not necessarily the result of the same storm. This difference is the result of changes in storm paths and variances in climatological and astronomical tide conditions at the different locations within the Region.

TABLE 10-2
RECENT CHESAPEAKE BAY STORMS

STORM	TIDAL ELEVATIONS (Feet Above Mean Sea Level)			
	Norfolk	Mid-Bay	Washington	Baltimore
August 1933	8.0	7.3	9.6	8.2
September 1936	7.5	—	3.0	2.3
October 1954 "Hazel"	3.3	4.8	7.3	6.0
August 1955 "Connie"	4.4	4.6	5.2	6.9
August 1955 "Diane"	4.4	4.5	5.6	5.0
April 1956 "Northeaster"	6.5	2.8	4.0	3.3
March 1962 "Northeaster"	7.4	6.0	—	4.7

The hurricane of 23 August 1933 was the most destructive of record in the Bay Region. The hurricane center entered the mainland near Cape Hatteras, passed slightly west of Norfolk, Virginia, and continued in a northerly direction passing just east of Washington, D.C. The storm surge in the Bay and tidal tributaries was the highest of record and moved at near the critical speed for producing the maximum surge, which in this case coincided with the astronomical high tide as it proceeded upstream. The results were tides ranging from 8.0 feet above mean sea level (msl) at Norfolk to as high as 9.6 feet (msl) at Washington, D.C. In addition to flooding damage, the high winds associated with this storm generated very destructive waves which caused extensive shoreline erosion. An accurate evaluation of the damage resulting from the flood is not available; however, the best estimate by the U.S. Weather Bureau following the storm was $17,000,000 for the Bay area.

For comparative purposes, Table 10-3 provides an estimate of the damages that resulted from four of the most damaging storms that passed through the Bay Region. The estimates reflect historical damages that have been updated to reflect 1975 price levels and as such do not reflect the damages that would result from a recurrence of these storms under today's conditions.

TABLE 10-3
TIDAL FLOOD DAMAGES

LOCATION	STORMS AND DAMAGES IN THOUSANDS OF DOLLARS			
	August 1933	October 1954 "Hazel"	August 1955 "Connie"	March 1962
Baltimore Metro Area	$23,500	$6,900	$11,500	Negligible
Washington Metro Area	12,000	4,800	300	Negligible
Maryland Tidewater Area	11,400	9,100	1,800	Negligible
Norfolk Metro Area	8,500	Negligible	Negligible	$ 4,800
Virginia Tidewater Area	Negligible	Negligible	Negligible	24,700

It should be noted that the above discussion was directed toward those storms that produced major tidal flooding. Conspicuous by their absence is any reference to storms such as Tropical Storm Agnes which was the most damaging storm ever experienced in the Chesapeake Bay drainage area. As in the case of Agnes, there have been numerous tropical storms that have caused significant fluvial flooding in the upstream portions of the Bay's tributaries but that produced no associated tidal flooding in the Bay itself.

DESCRIPTIVE PUBLICATIONS

In addition to the supporting studies mentioned in Chapter I, there were several additional sources of information used in the development of this appendix. Existing and proposed land use along the shoreline was based on land use mapping found in the various country and regional land use documents. Land use mapping prepared by the U.S. Geological Survey as part of the Central Atlantic Regional Ecological Test Site (CARETS) Program was also used where county or regional land use data were not available. U.S. Geological Survey Quadrangles sheets depicting flood prone areas and National Weather Service Storm Evacuation Maps were used, where available, as a guide in defining the areas subject to tidal flooding. Historical tidal flooding elevations were obtained from the tidal gage records of the National Ocean Survey.

PRESENT STATUS

EXISTING PROBLEMS AND CONFLICTS

As the historical development of the Bay Region has been tied in large part to the Bay itself, considerable development has taken place along the shoreline. Over the years this shoreline development has been subjected to periodic tidal flooding and the damages sustained have been substantial. The damages sustained have included loss of life and property, hazards to health, disruption of normal economic activities, and the cost of evacuation and rehabilitation. The primary problem then as it relates to tidal flooding is the conflict between a natural process and man's existing and proposed use of the tidal flood plain.

In addition to man-related developments, tidal flooding can also have significant impacts on the natural environment. Tidal flooding can cause substantial erosion of the shoreline and the loss of both aquatic plants and shoreline vegetation. The further intrusion of saline water and the even temporary disruption of normal salinity patterns can have serious effects on the biota of the Bay. With the importance of commercial and sport fishing in the Region, any mortalities or disruption of the important finfish and shellfish can have a significant economic impact on the fisheries industry.

An additional conflict is the environmental impact of the various structural measures employed to prevent tidal flooding. Many times the flood control structures are constructed in the intertidal zone and the adjacent shallow water areas. In such cases, the structure and any associated land fill often causes the loss of wetland habitat for many species of estuarine fish and wildlife. Structural measures can also alter current patterns and affect the flushing action in the vicinity of the structure.

EXISTING FLOOD PRONE AREAS

Existing flood problem areas were identified by considering the degree of tidal flooding that would be experienced by those communities located along the shoreline of the Bay and its tributaries. While it is recognized that non-urban land uses like agriculture would suffer significant damages the analysis was limited to communities or urbanized areas, as residential, commercial, and industrial development would suffer the greatest monetary losses as a result of a tidal flood.

The initial step in the analysis was to identify all Bay communities having a population of 1,000 or greater than are located either in total or in part within the Standard Project Tidal Flood Plain. The Standard Project Tidal Flood is defined as the largest tidal flood that is likely to occur under the most severe combination of meteorological and hydrological conditions that are considered *reasonably* characteristic of the geographic region. The Corps of Engineers in cooperation with the U.S. Weather Bureau determined that for the Chesapeake Bay Region the Standard Project Tide would average approximately 13 feet above mean sea level (msl). The above figure is a static or standing water surface elevation which would occur in conjunction with an astronomical high tide and does not include the effects of waves. Wave heights are dependent upon wind speed and direction, depth of water, fetch (the distance the wind blows over the water in generating the waves) and the length of time the wind blows. Assuming average values for water depth and fetch and superimposing winds characteristic of a hurricane that would produce a tidal surge of 13 feet above msl, wave heights on the Bay could be 5 feet in height. Based on the above combination of tidal surge and wave action the Standard Project Tidal Flood would inundate all areas up to approximately 18 feet above msl.

Based on the fact that average conditions were used in determining the above Standard Project Tide elevation and for ease in delineating the flooded area, an elevation of 20 feet msl was assumed for purposes of the analysis. Table 10-4 lists those communities that were found to be within the Standard Project Tidal Flood plain as defined by the 20 foot msl contour.

The next step in the flooding analysis was to identify those communities listed on Table 10-4 that should be classified as flood prone. In order for a community to be designated as flood prone, at least 50 acres of land that were developed for intensive use had to be inundated by the Standard Project Tide. Intensive land use was defined as residential (four dwelling units/acre or greater), commercial (including institutional), or industrial development.

TABLE 10-4
BAY COMMUNITIES SUBJECT TO FLOODING
FROM THE STANDARD PROJECT TIDAL FLOOD

MARYLAND

Anne Arundel County

Arundel on the Bay
Avalon Shores (Shadyside, Curtis Pt. to Horseshoe Pt. and West Shady Side)
Bay Bridge (At Western Shore to Moss Pond)
Bembe Beach
Broadwater
Columbia Beach
Deale
Eastport
Franklin Manor on the Bay and Cape Anne
Galesville
Rose Haven

Baltimore County

Back River Neck
Dundalk (Including Sparrows Point)
Middle River Neck
Patapsco River Neck

Charles County

Cobb Island

Dorchester County

Cambridge

Harford County

Havre de Grace

Kent County

Rock Hall

Queen Annes County

Dominion
Grasonville
Stevensville

TABLE 10-4 (cont'd)
BAY COMMUNITIES SUBJECT TO FLOODING FROM THE STANDARD PROJECT TIDAL FLOOD

MARYLAND (cont'd)

Baltimore City

Calvert County

Cove Point
North Beach on the Bay
Solomons Island

Caroline County

Choptank
Denton
Federalsburg

Cecil County

Elkton
Northeast

Wicomico County

Bivalve
Nanticoke
Salisbury

St. Marys County

Colton
Piney Point
St. Clement Shores
St. George Island

Somerset County

Crisfield
Smith Island

Talbot County

Bellevue
Easton
Oxford
St. Michaels
Tilghman Island

Worcester County

Pocomoke City
Snow Hill

VIRGINIA

Independent Cities

Alexandria
Fredericksburg
Hampton
Norfolk
Portsmouth
Virginia Beach
Chesapeake
Newport News

Accomack County

Onancock
Saxis
Tangier Island
Wachapreague

King George County

Dahlgren

King William County

West Point

Northampton County

Cape Charles

Westmoreland County

Colonial Beach

TABLE 10-4 (cont'd)
BAY COMMUNITIES SUBJECT TO FLOODING
FROM THE STANDARD PROJECT TIDAL FLOOD

VIRGINIA (cont'd)

Essex County	York County
Tappahannock	Poquoson

WASHINGTON, D.C.

The existing land use was determined from either regional and county land use planning documents or the existing land use maps prepared by the U.S. Geological Survey under the CARETS Program. Those communities found to be flood prone together with the area inundated for each intensive land use are shown on Table 10-5. The map reference numbers refer to Plates 10-1 through 10-3 included at the end of the appendix.

The last step in the flooding analysis was to further examine the communities listed as flood prone on Table 10-5 and classify each as to whether or not the tidal flood problem was considered to be critical. The flood problem was considered to be critical if 25 acres or more of intensively developed land was inundated by the Intermediate Regional Tidal Flood and it also appeared that the existing development would suffer significant damage from that same flood.

The Intermediate Regional Tidal Flood is defined as that tidal flood having an average frequency of occurrence of once in 100 years, although the flood could occur in any year. Based on tidal frequency studies conducted for Baltimore, Maryland; Washington, D.C.; and Colonial Beach, Virginia; the tidal flood that resulted from the August 1933 storm very closely approximates the 100-year occurrence in each of these cities. Based on this comparison it was assumed for this analysis that the flood elevations from the August 1933 storm would be representative of a 100-year occurrence throughout the Maryland Portion of the Bay and tributaries. The recorded elevations from the approximately 50 tide gages that were operating during the August 1933 storm were used to define the flood area in the flood-prone communities in Maryland. The flood heights used were found to range between 6.0 and 11.0 feet above msl.

TABLE 10-5
FLOOD PRONE COMMUNITIES

MAP REFERENCE NUMBER	COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)			
		Residential	Industrial	Commercial	Total
	STATE OF MARYLAND				
	Anne Arundel County				
7	Arundel on the Bay	502	0	0	502
9	Avalon Shores (Shady Side, Curtis Pt. to Horseshoe Pt. and West Shady Side)	695	47	9	751
3	Broadwater	62	0	0	62
1	Columbia Beach	168	0	0	168
4	Deale	369	0	36	405
5	Eastport	292	0	209	501
2	Franklin Manor on the Bay and Cape Anne	366	20	10	396
12	Galesville	152	0	4	156
11	Rose Haven	302	0	14	316
	Baltimore County				
15	Back River Neck	1,440	0	0	1,440
60	Dundalk (Including Sparrows Point)	2,400	1,490	0	3,890
14	Middle River Neck	680	0	0	680
13	Patapsco River Neck	900	0	0	900

TABLE 10-5 (cont'd)
FLOOD PRONE COMMUNITIES

MAP REFERENCE NUMBER	COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres) Residential	Industrial	Commercial	Total
	STATE OF MARYLAND (cont'd)				
56	Baltimore City	346	2,887	727	3,960
	Calvert County				
16	Cove Point	65	0	0	65
18	North Beach on the Bay	170	0	0	170
17	Solomons Island	109	0	32	141
	Caroline County				
19	Choptank	90	0	10	100
21	Denton	74	44	0	118
20	Federalsburg	120	76	0	196
	Cecil County				
22	Elkton	68	11	0	79
23	Northeast	60	20	0	80

TABLE 10-5 (cont'd)
FLOOD PRONE COMMUNITIES

MAP REFERENCE NUMBER	COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)			
		Residential	Industrial	Commercial	Total
	STATE OF MARYLAND (cont'd)				
	Charles County				
24	Cobb Island	321	0	11	332
	Dorchester County				
25	Cambridge	1,010	73	34	1,117
	Harford County				
26	Havre de Grace	50	10	60	120
	Kent County				
27	Rock Hall	197	24	9	230
	Queen Annes County				
30	Dominion	89	0	0	89
28	Grasonville	588	0	0	588
29	Stevensville	157	0	17	174

TABLE 10-5 (cont'd)
FLOOD PRONE COMMUNITIES

MAP REFERENCE NUMBER	COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)			
		Residential	Industrial	Commercial	Total
	STATE OF MARYLAND (cont'd)				
	St. Marys County				
32	Colton	146	0	0	146
61	Piney Point	298	120	14	432
34	St. Clement Shores	92	0	0	92
33	St. George Island	154	0	0	154
	Somerset County				
31	Crisfield	417	140	74	631
58	Smith Island	218	0	0	218
	Talbot County				
37	Easton	183	17	0	200
35	Oxford	110	20	0	130
36	St. Michaels	328	0	36	364
38	Tilghman Island	242	0	0	242

TABLE 10-5 (cont'd)
FLOOD PRONE COMMUNITIES

MAP REFERENCE NUMBER	COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)			
		Residential	Industrial	Commercial	Total
	STATE OF MARYLAND (cont'd)				
	Wicomico County				
40	Bivalve	62	0	0	62
39	Nanticoke	200	0	0	200
41	Salisbury	319	120	56	495
	Worcester County				
43	Pocomoke City	258	27	14	299
42	Snow Hill	139	137	20	296
	COMMONWEALTH OF VIRGINIA				
	Independent Cities				
62	Chesapeake	3,780	1,250	950	5,980
51	Fredericksburg	308	0	283	591
44	Hampton	14,390	180	970	15,540
63	Newport News	640	80	40	760
45	Norfolk	17,380	1,330	6,530	25,240
46	Portsmouth	6,045	35	1,085	7,165
50	Virginia Beach	4,610	0	1,330	5,940

TABLE 10-5 (cont'd)
FLOOD PRONE COMMUNITIES

MAP REFERENCE NUMBER	COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)			
		Residential	Industrial	Commercial	Total
	COMMONWEALTH OF VIRGINIA (cont'd)				
	Accomack County				
54	Onancock	207	0	17	224
55	Saxis	72	1	3	76
59	Tangier Island	326	0	0	326
47	King George County				
	Dahlgren	358	0	72	430
	King William County				
48	West Point	180	92	53	325
	Northampton County				
49	Cape Charles	131	4	13	148
	Westmoreland County				
52	Colonial Beach	350	0	16	366

TABLE 10-5 (cont'd)
FLOOD PRONE COMMUNITIES

MAP REFERENCE NUMBER	COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)			
		Residential	Industrial	Commercial	Total
	COMMONWEALTH OF VIRGINIA (cont'd)				
	York County				
53	Poquoson	1,070	0	0	1,070
57	Washington, D.C.	564	538	1,559	2,661

In the southern Virginia portion of the Bay, specific frequency studies have been conducted by the Corps of Engineers which show that the 100-year occurrence would produce flood heights approximately 9.0 feet above msl. The 100-year flood elevations used in this analysis are shown on Plates 10-1 through 10-3.

A detailed survey and compilation of the damages expected from the 100-year flood was beyond the scope of this analysis. Instead, an assessment of the flood damage to the development within the 100-year flood plain was made based on evaluations of topographic mapping and aerial photography and field visits to each of the flood prone communities. Damage was considered to be significant if the 100-flood exceeded the first floor elevation of the majority of the development.

Based on the area flooded by the 100-year tidal flood and an assessment of the potential for flood damages, the communities listed in Table 10-6 are classified as critical flood prone areas. Table 10-6 also includes the area that would be inundated by the 100-year tidal flood.

TABLE 10-6
CRITICAL FLOOD PRONE COMMUNITIES

COMMUNITY	AREA FLOODED BY THE 100-YEAR TIDAL FLOOD (Acres)			
	Residential	Industrial	Commercial	Total
STATE OF MARYLAND				
Anne Arundel County				
Arundel on the Bay	101	0	0	101
Avalon Shores (Shady Side, Curtis Pt. to Horseshoe Pt. and West Shady Side)	134	0	3	137
Deale	131	0	9	140
Baltimore County				
Dundalk (Including Sparrows Point)	920	1,350	0	2,270
Middle River Neck	426	0	0	426
Patapsco River Neck	590	0	0	590
Baltimore City	189	1,479	385	2,053
Caroline County				
Denton	0	26	0	26
Dorchester County				
Cambridge	33	60	23	116

TABLE 10-6 (cont'd)
CRITICAL FLOOD PRONE COMMUNITIES

COMMUNITY	AREA FLOODED BY THE 100-YEAR TIDAL FLOOD (Acres)			
	Residential	Industrial	Commercial	Total
STATE OF MARYLAND (cont'd)				
Kent County				
Rock Hall	141	5	0	146
Queen Annes County				
Grasonville	438	0	0	438
St. Marys County				
Piney Point	235	120	14	369
Somerset County				
Crisfield	417	140	74	631
Smith Island	218	0	0	218
Talbot County				
St. Michaels	258	0	23	281
Tilghman Island	242	0	0	242

TABLE 10-6 (cont'd)
CRITICAL FLOOD PRONE COMMUNITIES

COMMUNITY	AREA FLOODED BY THE 100-YEAR TIDAL FLOOD (Acres)			
	Residential	Industrial	Commercial	Total
STATE OF MARYLAND (cont'd)				
Wicomico County				
Salisbury	14	102	20	146
Worcester County				
Pocomoke City	53	104	8	165
Snow Hill	33	51	12	96
COMMONWEALTH OF VIRGINIA				
Independent Cities				
Chesapeake	2,470	1,220	520	4,210
Fredericksburg	8	0	23	31
Hampton	5,580	25	200	5,805
Norfolk	5,707	1,156	131	6,994
Portsmouth	1,300	30	27	1,357
Virginia Beach	1,020	0	100	1,126
Accomack County				
Tangier Island	326	0	0	326

TABLE 10-6 (cont'd)
CRITICAL FLOOD PRONE COMMUNITIES

COMMUNITY	AREA FLOODED BY THE 100-YEAR TIDAL FLOOD (Acres)			
	Residential	Industrial	Commercial	Total
COMMONWEALTH OF VIRGINIA (cont'd)				
King George County				
Dahlgren	29	0	0	29
King William County				
West Point	120	65	53	238
Northampton County				
Cape Charles	103	0	9	112
Westmoreland County				
Colonial Beach	320	0	16	336
York County				
Poquoson	1,070	0	0	1,070
Washington, D.C.	35	187	305	527

MANAGEMENT RESPONSIBILITIES

There are several Federal and State programs which provide varying degrees of assistance regarding tidal flooding problems. The services range from technical advice to funding the design and construction of structural protection measures. The following paragraphs list those Federal and State agencies which have flood control programs and/or management responsibilities.

STATE OF MARYLAND

Within the State of Maryland the Department of Natural Resources and the Department of State Planning are the two state agencies most directly concerned with tidal flooding. The Department of Natural Resources is responsible for: (1) granting permits for construction of shoreline erosion and flood control structures; (2) providing technical assistance to local governments to interpret flood information and draft local land use regulations pertaining to areas subject to flooding; (3) reviewing plans for local public works and exercising regulatory control over them; (4) administering financial assistance for flood control as funds are made available; and (5) developing Maryland's Coastal Zone Management Plan.

The Department of State Planning has the responsibility for the preparation of a Generalized State Land Use Plan as an element of the overall State Development Plan. The Department is also required to: (1) coordinate with Federal, State, and local government agencies during the preparation of the State Development Plan; (2) designate areas of critical state concern to include flood plains; (3) establish statewide data referencing standards; (4) establish a depository of state and local comprehensive and functional plans; and (5) intervene in administrative or judicial proceedings involving land use decisions to represent the interests of the state.

Regarding local government regulations as they pertain to the use of the flood plain, Table 10-7 shows the type of regulations and the review standard for each of the Maryland counties within the study area. The information on Table 10-7 was taken from a report entitled *Regulating Flood-Prone Land in Maryland*, May 1975, and prepared by the Maryland Department of State Planning. Referring to the classifications shown on Table 10-7, Class 1 is used for those jurisdictions which have enacted regulations restricting development within clearly defined flood-

prone areas. Jurisdictions which have enacted regulations or established procedures which restrict harmful development within flood-prone areas not geographically or legislatively delineated are with Class 2. Class 3 jurisdictions are those which may provide some administrative review for the identification of flood hazard areas, but have failed to enact regulations or administrative guidelines regarding flood-prone areas.

COMMONWEALTH OF VIRGINIA

Within the Commonwealth the State Water Control Board functions as the water quality regulation agency. The Board is also responsible for (a) developing water resources management plans for the Commonwealth's waters, (b) providing technical assistance to local governments for the control of flooding and, (c) publicizing and interpreting the Federal Flood Insurance program for municipalities and counties with a view toward allowing maximum community eligibility. The Virginia Institute of Marine Science serves as a technical advisor to other Commonwealth agencies and conducts the full range of engineering and environmental studies in the coastal zone.

As in Maryland, many of the local jurisdictions in Virginia have adopted or are in the process of formulating flood plain land use regulations. The Virginia Uniform Statewide Building Code has been amended to require that all future residential construction in the flood plain, be built with first floor elevations at or above the 100-Year Flood Level. New residential structures may still be built below that level but must be flood proofed to that level.

U.S. ARMY CORPS OF ENGINEERS

The Congress has directed the Corps of Engineers to carry out programs established to protect and maintain the Nation's shorelines. One of the programs includes the construction of shore protection and beach restoration projects that provide protection against tidal flooding and shoreline erosion.

The Federal interest in hurricane and abnormal tidal flood damage protection is not explicitly defined by legislation. The Federal concern has been established by Congressional authorization of such projects on a case-by-case basis. Projects providing hurricane and tidal flood protection authorized in the 1958 Flood Control Act established a precedent of limiting the Federal share of project cost to a maximum of 70

TABLE 10-7
SUMMARY OF JURISDICTIONS WITH REGARD TO THEIR ABILITY TO CONTROL USES WITHIN FLOOD–PRONE AREAS[1]

Jurisdiction	Classification	Review Standard
Anne Arundel County	1	100-year floodplain
Baltimore City	3	Not Clear
Baltimore County	2	100-year floodplain
Calvert County	1	50-year floodplain
Caroline County	2	Land subject to periodic flooding
Carroll County	1	100-year floodplain
Cecil County*	2	Land subject to frequent flooding
Charles County	2	Construction must be consistent with the need to minimize flood damage
Dorchester County	3	Flood-prone land and wetlands
Harford County	2	100-year floodplain
Howard County	1	100-year floodplain
Kent County	2	Land subject to periodic flooding
Montgomery County	1	50-year floodplain
Prince George's County	1	50-year floodplain
Queen Anne's County	2	Land subject to periodic flooding
St. Mary's County	2	100-year floodplain
Somerset County	3	None
Talbot County	2	50-year Floodplain
Wicomico County	2	Land subject to periodic flooding
Worcester County	2	Areas subject to flooding and erosion from ocean water.

*Cecil County is placed in a Class 2 category because the floodplain district is applicable to only a small portion of the County's flood-prone areas.

[1]This table was taken from a report titled *Regulating Flood-Prone Land in Maryland*, May 1975, Maryland Department of State Planning.

percent. It has been Corps practice to include similar cost sharing for all subsequent justified hurricane protection projects recommended for Congressional authorization. When the normal local costs of lands, easements, rights-of-way, and relocations amount to less than 30 percent of total first costs, the difference is required as a local cash contribution; when local costs exceed 30 percent, they become the minimum requirement. Successful protection against hurricane and tidal flooding on the open coast frequently requires that the shoreline be concomitantly stabilized against erosion. For multiple-purpose hurricane protection and beach erosion control projects, Section 208 of the 1970 Flood Control Act provides discretionary power to the Secretary of the Army to authorize a Federal share up to 70 percent of the project costs exclusive of land costs.

In order to determine if any Federal participation is warranted in a tidal flood control project, the Corps may undertake an investigation under specific authorization by Congress or resolutions by either the House or Senate Public Works Committees. Given the authority and the study funding, the Corps investigates the engineering and economic feasibility of various control measures and their associated environmental and socio-economic impacts and makes recommendations to Congress regarding solutions to the problem. If approved and authorized by the Congress, Federal funds in accordance with the aforementioned limitations may be used for the design and construction of a project.

The Corps may also undertake investigations under general continuing authorities. Section 205 of the 1948 Flood Control Act provides authority for the Corps to develop and construct small flood control projects that have not already been specifically authorized by Congress. A project is adopted for construction under Section 205 only after

detailed investigation and study have evaluated the engineering feasibility, economic justification, and the environmental and socio-economic impact of the project. Each project is limited to a Federal cost of not more than $2,000,000 unless the area has been declared a major disaster area within a five year period which raises the limit to $3,000,000.

The Corps is authorized by Section 206 of the 1960 FC Act, as amended, to provide information, technical planning assistance, and guidance to non-Federal entities in identifying the magnitude and extent of the flood hazard and in planning wise use of the flood plains. It also provides basic hydrologic and damage information to the Federal Flood Insurance Administration under reimbursable agreement. Direct response and assistance of this kind are provided through the Flood Plain Management Services Program. Section 55 of the Water Resources Development Act of 1974 is similar to Section 206 above except that it focuses on shore and streambank erosion instead of tidal flooding.

The Corps also has the authority to participate in emergency activities. These activities include: flood emergency preparation, flood fighting, rescue operations and emergency repairs and restoration. Existing policy views flood emergency operations by the Corps as a supplement to individual and local community efforts, rather than as replacements for them. Local assurances and appropriate requests for assistance must be furnished by non-Federal interests. The Corps emergency measures are temporary in nature and are designed to meet the immediate threat only.

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE (SCS)

The SCS was created by the Soil Conservation Act in 1935, originally for the purposes of developing and maintaining a national soil and conservation program. In 1954, the Watershed Protection and Flood Prevention Act expanded its mission to preserving and protecting the Nation's land and water resources.

Under the 1954 Act, SCS is authorized to conduct small watershed investigations. Under the Flood and Agriculture Act of 1962, the SCS is also responsible for assisting local groups in the sponsorship of long-range resource planning and development. Under these statutes, the SCS provides:

(1) Technical assistance to individual landowners for treating and using land.

(2) Technical and financial assistance for water shed protection and flood prevention for areas no larger than 250,000 acres (Small Watershed Program).

(3) Planning and development assistance in larger areas (Resource Conservation and Development Program). Recipients of assistance are public agencies and nonprofit organizations.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The Federal responsibility for administering the Coastal Zone Management Act has been assigned to the Office of Coastal Zone Management (OCZM) of the National Oceanic and Atmospheric Administration (NOAA) under the direction of the Secretary of Commerce. NOAA serves as the primary Federal-State coordinating entity and will administer the grant program which may finance up to two-thirds of the annual costs of State CZM program development and implementation. NOAA will monitor the administration of State CZM plans to insure that they are refined and updated as needed.

In an effort to assist civilian authorities in preparing for a tidal flood, NOAA also has a program for the preparation of storm evacuation maps. The maps when completed will cover the entire Atlantic Coast and the Gulf Coast to a scale of 1:62,500 and will show both flood zones and suggested evacuation routes. The four flood zones shown on the maps will not depict historical or projected flood areas, but will indicate the areas inundated between mean sea level and 20 feet above mean sea level at 5 foot intervals. Thus, given a projected tide level, local officials can refer to the mapping to determine threatened areas and the best evacuation routes for people living in those areas. At the present time evacuation maps have been completed for only the Norfolk, Virginia Beach, Poquoson and Cape Charles, Virginia areas within the Bay Region.

U.S. GEOLOGICAL SURVEY

The Water Resources Division of the U.S. Geological Survey (USGS) is responsible for the investigation and appraisal of the source, quantity, quality, distribution, movement, and availability of both surface and ground waters. This work includes investigations of floods and droughts, interpretive studies of existing or potential water problems, research in the field of hydrology and related sciences, and providing to other Federal agencies scientific and technical assistance in appropriate fields. USGS also has the responsibility for coordination of Federal activities in the acquisition of water data, including the design and operation of a national network. The Division is unique in the extent to which it shares with State and local agencies the responsibility for planning and financing water-resources investigations.

Part of the Water Resources Division's work includes the preparation of flood hazard maps which delineate the approximate boundary of the 100-year flood. While detailed hydrologic studies are not conducted in order to define the flood limits, the mapping serves as a general indication of flood hazard areas and may be used as a basis for setting priorities for more detailed studies.

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Until recently, insurance against flood-caused losses was virtually non-existent. Now, however, flood insurance is available in flood-prone communities under the Federally-subsidized National Flood Insurance Program.

A cooperative effort of the Federal government and the private insurance industry, the program is operated by the Federal Insurance Administration of the U.S. Department of Housing and Urban Development (HUD). In return for making low cost insurance available for existing flood-prone property, the program places certain obligations upon the community. The community is required to adopt and enforce land use and other control measures that will guide new development in flood-prone areas so that flood damage is avoided or reduced.

One of the keys to the flood insurance program is the identification of the community's flood hazard areas. To obtain the information needed to designate these areas, the Federal Insurance Administration is pro-

vided information by other Federal, State, and local agencies.

The Flood Disaster Protection Act of 1973 requires the purchase of flood insurance after March 2, 1974, as a condition of receiving any form of Federal or federally-related financial assistance for acquisition or construction purposes in an identified flood plain area that is located within any community currently participating in the National Flood Insurance Program. Other communities not participating in the Flood Insurance Program, but that have been notified of their tentative identification as having one or more flood hazard areas, have one year upon such identification to participate in the program or forego federally-related financial assistance that can be legally provided for acquisition or construction in an identified flood hazard area.

Communities entering the National Flood Insurance Program generally do so in two phases. They first become eligible for the sale of flood insurance in the Emergency Program under which only half of the program's total limits of coverage are available and all such insurance is sold at subsidized premium rates. After the flood insurance rate study has been completed, a community enters the Regular Program under which full limits of coverage are available. Table 10-8 lists the Maryland and Virginia communities that are subject to tidal flooding and that are participating in the Flood Insurance Program as of December 1975.

Regarding other activities of the Federal Insurance Administration (FIA), a Bay-wide tidal flooding program is planned. The program will include the determination of tidal flood heights and areas inundated for a full range of frequencies.

TABLE 10-8
LOCAL JURISDICTIONS PARTICIPATING IN
THE NATIONAL FLOOD INSURANCE PROGRAM (1)

MARYLAND

Anne Arundel County
  Annapolis
  Highland Beach

Baltimore County

Baltimore City

Calvert County
  Chesapeake Beach
  North Beach

Caroline County
  Denton
  Greensboro
  Hillsboro

Cecil County
  Cecilton
  Charlestown
  Chesapeake City
  Elkton
  Northeast
  Perryville
  Port Deposit

Charles County
  Indian Head

Dorchester County
  Cambridge
  Eldorado
  Federalsburg
  Secretary
  Vienna

Harford County
  Aberdeen
  Havre de Grace

Kent County
  Betterton
  Chestertown
  Millington
  Rock Hall

Prince Georges County

Queen Annes County
  Centreville
  Church Hill
  Queenstown

Somerset County
  Crisfield
  Princess Anne

St. Marys County
  Leonardtown

Talbot County
  Easton
  Oxford
  St. Michaels

Wicomico County
  Mardella Springs
  Salisbury
  Sharptown

Worcester County
  Pocomoke City
  Snow Hill

(1) As of December 31, 1975.

TABLE 10-8 (cont'd)
LOCAL JURISDICTIONS PARTICIPATING IN THE NATIONAL FLOOD INSURANCE PROGRAM

VIRGINIA

Independent Cities
- Alexandria
- Chesapeake City
- Colonial Heights
- Fredericksburg
- Hampton
- Hopewell
- Newport News
- Norfolk
- Portsmouth
- Richmond
- Suffolk
- Virginia Beach
- Williamsburg

Accomack County
- Tangier

Arlington County

Caroline County

Charles City County

Chesterfield County

Essex County
- Tappahannock

Fairfax County

Gloucester County

Henrico County

Isle of Wight County
- Smithfield

James City County

King George County

King William County
- West Point

King & Queen County

Lancaster County
- Irvington
- White Stone

Mathews County

Middlesex County
- Urbanna

New Kent County

Northampton County
- Cape Charles

Northumberland County

Prince George County

Prince William County
- Dumfries
- Occoquan
- Quantico

Richmond County

Southampton County

Stafford County

Surry County
- Claremont

Westmoreland County
- Colonial Beach

York County
- Poquoson

CHAPTER III

FUTURE TIDAL FLOOD PROBLEM AREAS

In addition to defining the urban areas that are presently subject to tidal flooding, it is equally important to delineate those areas that have the potential to become problem areas dependent on their future development. As discussed in this chapter, the approach used to define the future problem areas parallels that used to define the existing problems. By defining the emerging problem areas, appropriate structural or nonstructural measures may be employed by both the public and private sectors to avoid future flood problems.

ASSUMPTIONS AND METHODOLOGY

As noted above, the method employed to delineate potential future problem areas is essentially the same as that used to define the existing flood-prone and critical areas. As before, the principal factors used in the analysis are projected tidal flood elevations and the flood plain land use.

For the future problem analysis it was again assumed that a Standard Project Tidal Flood having an elevation of 20 feet above msl would be used to delineate flood-prone areas. The Intermediate Regional Tidal Flood (100-year) as defined by the August 1933 and the 100-year northeaster was used as before to define the critical flood-prone areas.

Regarding land use it was assumed that future land use in the flood plain would be as shown in the latest regional, county, or municipal land use planning documents. While the local land use plans reflected that the projected level of development would be reached in time frames varying from 15 to 25 years, it was assumed for this analysis that the plans reflected optimum development of the area. It should be noted that several counties in the Northern Neck Area of Virginia to include Essex, Middlesex, King and Queen, Mathews, and King William presently have no future land use plans. For this analysis, it was assumed that the present land use in these predominantly rural counties would not change significantly in the planning period.

Given the projected tidal flood elevations and the expected future land use in the flood plain, the entire flood plain was reviewed to determine if any future development was proposed in areas subject to tidal flooding. As before, the criteria for delineation as a flood-prone area was that 50 acres or more of land proposed for intensive land use (residential, commercial or industrial) fall within the Standard Project Tidal Flood Plain. Areas were considered to be critically flood prone if 25 acres or more of land proposed for intensive land use was within the Intermediate Regional Tidal Flood Plain.

FUTURE PROBLEM AREAS

Using the assumptions and methodology discussed above, the additional flood plain areas found to be flood prone and critically flood prone are shown on Tables 10-9 and 10-10, respectively. The above tables list the community and both the existing and the projected future acreage that is subject to flooding. Based on a comparison of the existing and future acreage it should be noted that approximately 58,400 acres of land is proposed for intensive development with the Standard Project Tidal Flood Plain. Of even a more serious nature is the fact that approximately 19,500 acres of land within the 100-year flood plain is proposed for intensive development.

SENSITIVITY ANALYSIS

The purpose of this segment of the report is to provide an assessment of how sensitive the delineation of future flood prone areas is to the assumptions made in the adopted methodology. As indicated in the description of the methodology, the factors considered in the analysis were the projected flood elevations and the flood plain land use.

Regarding the projected flood elevations, a Standard Project Tidal Elevation of 20 feet above mean sea level was used as the criteria for delineation of flood prone areas. Critical flood prone areas were defined using the 100-year tidal elevation which was assumed to be a recurrence of the August 1933 tidal flood and the 100-year "Northeaster" in the Maryland and Virginia portions of the Bay, respectively.

For this sensitivity analysis the effect of changing the criteria for selection of the critical flood prone areas from the 100-year to the

50-year tidal flood was investigated. An examination of tidal frequency curves at Baltimore; Washington, D.C.; Colonial Beach; and Norfolk shows that the 50-year tidal flood would produce elevations approximately 1 foot lower than the 100-year occurrence. Based on a review of eight typical communities investigated in the flooding analysis, the area inundated by the 50-year tide would be approximately 10 percent less than the area inundated by the 100-year tide. While a 10 percent reduction in acreage is significant, it should be noted that all communities listed on Table 10-10 would still be classified as critical flood prone areas if the 50-year tidal flood was adopted as a criteria.

As discussed above, future flood plain land use was the other factor used in the flooding analysis. The future land use in the flood plain was based entirely on the land use plans prepared by local and regional planning agencies. In the event the future land use as portrayed in the planning documents changes, it could directly affect the classification of a community as a critical flood prone area. For example, if a segment of the 100-year flood plain previously zoned as agricultural is reclassified as residential, it could qualify as critical. As another example, recent trends toward zoning for less intensive use of shorelands because of the threat of shoreline erosion or tidal flooding could result in significantly less flood plain qualifying as critical.

The results of the above sensitivity analysis indicate that dependent on the basic assumptions made the amount of flood plain that should be classified as critical can vary significantly. It is felt, however, that the communities designated as critical in this appendix would qualify as critical under a broad range of criteria and as such should receive a more detailed analysis of their existing and projected flood problems.

TABLE 10-9
FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres) PROPOSED DEVELOPMENT				EXISTING DEVELOPMENT	TOTAL
	Residential	Industrial	Commercial	Total		
STATE OF MARYLAND						
Anne Arundel County						
Arundel on the Bay	665	0	0	665	502	1,167
Avalon Shores (Shady Side, Curtis Pt. to Horseshoe Pt. and West Shady Side)	1,329	0	0	1,329	751	2,080
Bay Bridge (Western Shore to Moss Pond)	0	198	0	198	14	212
Bembe Beach	218	0	0	218	0	218
Broadwater	633	0	0	633	62	695
Columbia Beach	513	0	0	513	168	681
Deale	378	0	20	398	405	803
Franklin Manor on the Bay	1,280	0	0	1,280	396	1,676
Rose Haven	281	0	1	282	316	598
Shady Oaks	605	0	0	605	104	709
Baltimore County						
Back River Neck	1,650	50	50	1,750	1,440	3,190
Dundalk (Including Sparrows Point)	-200[1]	2,940	65	2,805	3,890	6,695

[1]Negative values indicate a change in land use, i.e., a shift in intensive land uses between the existing and future condition.

TABLE 10-9 (cont'd)
FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)					
	PROPOSED DEVELOPMENT				EXISTING	
	Residential	Industrial	Commercial	Total	DEVELOPMENT	TOTAL
	STATE OF MARYLAND (cont'd)					
Baltimore County (cont'd)						
Middle River Neck	1,750	0	0	1,750	680	2,430
Patapsco River Neck	-120[1]	400	0	280	900	1,180
Calvert County						
Cove Point	60	0	0	60	65	125
Solomons Island	19	82	0	101	141	242
Caroline County						
Choptank	105	0	0	105	100	205
Denton	-14[1]	68	0	54	118	172
Cecil County						
Elkton	522	-3[1]	17	536	79	615
Northeast	120	-20[1]	12	112	80	192

[1] Negative values indicate a change in land use, i.e., a shift in intensive land uses between the existing and future condition.

TABLE 10-9 (cont'd)
FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)					
	PROPOSED DEVELOPMENT				EXISTING	
	Residential	Industrial	Commercial	Total	DEVELOPMENT	TOTAL
	STATE OF MARYLAND (cont'd)					
Dorchester County						
Cambridge	849	85	71	1,005	1,117	2,122
Kent County						
Rock Hall	1,137	106	57	1,300	230	1,530
Queen Annes County						
Dominion	375	0	0	375	89	464
Grasonville	943	0	0	943	588	1,531
Stevensville	1,027	116	-17[1]	1,126	174	1,300
St. Marys County						
Colton	156	0	0	156	146	302
St. George Island	91	0	0	91	154	245

[1] Negative values indicate a change in land use, i.e., a shift in intensive land uses between the existing and future condition.

TABLE 10-9 (cont'd)
FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres) PROPOSED DEVELOPMENT Residential	Industrial	Commercial	Total	EXISTING DEVELOPMENT	TOTAL
	STATE OF MARYLAND (cont'd)					
Somerset County						
Smith Island	598	0	0	598	218	816
Talbot County						
Easton	141	-5[1]	0	136	200	336
Oxford	95	18	0	113	130	243
St. Michaels	16	92	92	200	364	564
Tilghman Island	120	42	0	162	242	404
Wicomico County						
Bivalve	388	0	0	388	62	450
Nanticoke	751	0	0	751	200	951
Salisbury	-137[1]	188	27	78	495	573

[1]Negative values indicate a change in land use, i.e., a shift in intensive land uses between the existing and future condition.

TABLE 10-9 (cont'd)
FUTURE FLOOD PRONE AREAS

COMMUNITY		AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres) PROPOSED DEVELOPMENT				EXISTING	
		Residential	Industrial	Commercial	Total	DEVELOPMENT	TOTAL
		STATE OF MARYLAND (cont'd)					
Worchester County							
Pocomoke City		2,628	248	-14[1]	2,862	299	3,161
	SUBTOTAL	18,972	4,605	381	23,958	14,919	38,877
		COMMONWEALTH OF VIRGINIA					
Independent Cities							
Chesapeake		9,020	4,570	1,380	14,970	5,980	20,950
Hampton		3,220	1,000	1,130	5,250	15,540	20,890
Norfolk		1,410	4,300	-5,560	150	25,240	25,390
Virginia Beach		8,700	0	510	9,210	5,940	15,150

[1] Negative values indicate a change in land use, i.e., a shift in intensive land uses between the existing and future condition.

TABLE 10-9 (cont'd)
FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE STANDARD PROJECT TIDE (Acres)					
	PROPOSED DEVELOPMENT				EXISTING	
	Residential	Industrial	Commercial	Total	DEVELOPMENT	TOTAL
	COMMONWEALTH OF VIRGINIA (cont'd)					
York County						
Poquoson	4,280	360	100	4,740	1,070	5,810
SUBTOTAL	26,630	10,230	-2,440[1]	34,420	58,770	88,190
WASHINGTON, D.C.	0	54	0	54	2,661	2,715
TOTAL	45,602	14,889	-2,059[1]	58,432	71,350	129,782

[1]Negative values indicate a change in land use, i.e., a shift in intensive land uses between the existing and future condition.

TABLE 10-10
CRITICAL FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE 100-YEAR TIDAL FLOOD (Acres) PROPOSED DEVELOPMENT					
	Residential	Industrial	Commercial	TOTAL	EXISTING DEVELOPMENT	TOTAL
STATE OF MARYLAND						
Anne Arundel County						
Arundel on the Bay	75	0	0	75	101	176
Baltimore County						
Dundalk (Including Sparrows Point)	-280[1]	1,550	10	1,280	2,270	3,550
Cecil County						
Elkton	40	2	0	42	20	62
Northeast	56	0	0	56	11	67
Kent County						
Rock Hall	308	74	23	405	146	551
Queen Annes County						
Grasonville	459	0	0	459	438	897
Stevensville	0	116	0	116	0	116

TABLE 10-10 (cont'd)
CRITICAL FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE 100-YEAR TIDAL FLOOD (Acres)					
	PROPOSED DEVELOPMENT				EXISTING DEVELOPMENT	TOTAL
	Residential	Industrial	Commercial	TOTAL		
STATE OF MARYLAND (cont'd)						
Somerset County						
Smith Island	598	0	0	598	218	816
Talbot County						
St. Michaels	41	0	50	91	281	372
Wicomico County						
Salisbury	3	34	22	59	146	205
Worcester County						
Pocomoke City	23	13	0	36	165	201
SUBTOTAL	1,323	1,789	105	3,217	3,796	7,013

[1]Negative values indicate a shift in land use between the existing and future condition.

TABLE 10-10 (cont'd)
CRITICAL FUTURE FLOOD PRONE AREAS

COMMUNITY	AREA FLOODED BY THE 100-YEAR TIDAL FLOOD (Acres)					
	PROPOSED DEVELOPMENT				EXISTING DEVELOPMENT	TOTAL
	Residential	Industrial	Commercial	TOTAL		
COMMONWEALTH OF VIRGINIA						
Independent Cities						
Chesapeake	2,680	1,120	420	4,220	4,210	8,430
Hampton	2,560	305	260	3,125	5,805	8,930
Norfolk	-207[1]	279	17	89	6,994	7,083
Virginia Beach	3,890	510	-100[1]	4,300	1,120	5,420
York County						
Poquoson	4,050	360	100	4,510	1,070	5,580
SUBTOTAL	12,973	2,574	697	16,244	19,199	35,443
TOTAL	14,296	4,363	802	19,461	22,995	42,456

CHAPTER IV
MEANS TO SATISFY NEEDS

This chapter is a survey of the various structural and nonstructural measures that can be employed to prevent or reduce the damages from tidal flooding. The applicability of the measures in various locations is also discussed together with the common failures that can be encountered as the result of improper design or construction.

STRUCTURAL SOLUTIONS

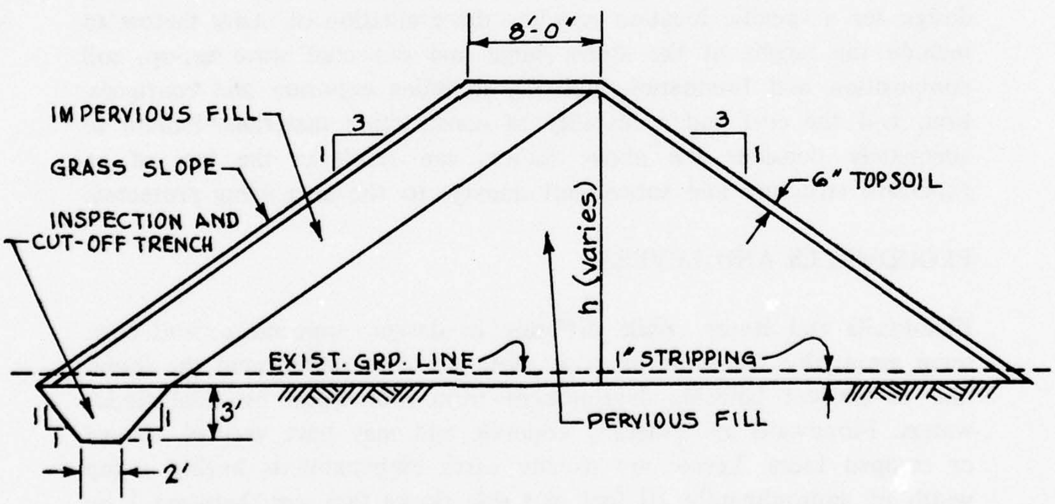
Structural solutions are defined as those man-made structures that are designed to protect an area from tidal flood damages. The following paragraphs include a discussion of levees, floodwalls, breakwaters, and harbors of refuge which are the most commonly used structural measures. Other structural measures to include bulkheads, revetments, groins and beach nourishment that are used primarily for shoreline erosion control also have some applicability as flood control measures. A detailed description of these measures is included in Appendix 11 - Shoreline Erosion.

It should be noted that the following information is provided only as a general description and not a detailed design. To develop a detailed design for a specific location requires the evaluation of many factors to include the height of the storm surge and expected wave set-up, soil composition and foundation material, shoreline exposure and configuration, and the cost and availability of construction materials. Failure to adequately consider the above factors can result in the loss of an expensive structure and subsequent damage to the area being protected.

FLOODWALLS AND LEVEES

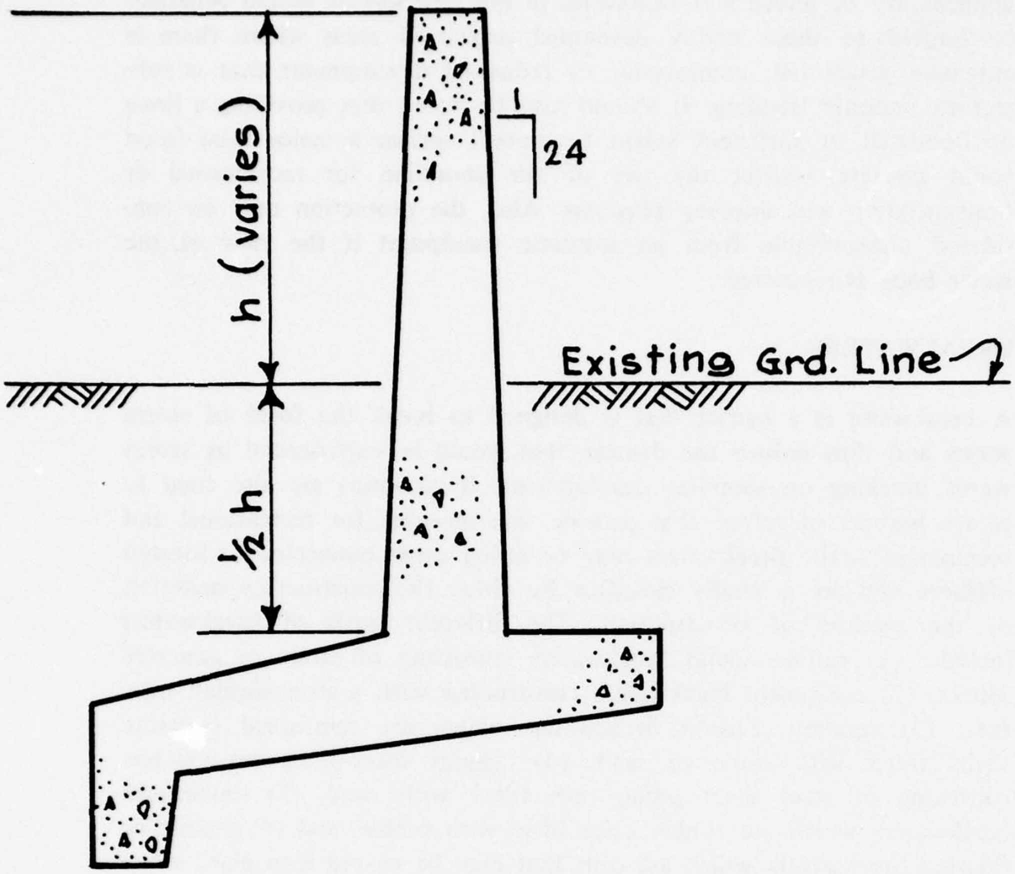
Floodwalls and levees, while differing in design, appearance, and cost, serve essentially the same purpose. Both are constructed near the shoreline to protect landside development from inundation by tidal floodwaters. Floodwalls are generally concrete and may have vertical, curved or stepped faces. Levees are usually earth embankments having a top width of approximately 10 feet and side slopes that vary between 1 on 2 and 1 on 4. Levees are generally less expensive than floodwalls and are particularly applicable in areas where construction materials are

nearby and there is sufficient area between the shoreline and the development for their construction. Floodwalls may be used where the close proximity of the development to the shoreline precludes the construction of levees. A typical example of a levee and a floodwall are included as Figures 10-2 and 10-3, respectively.



TYPICAL SECTION THRU EARTH LEVEE
(Not to Scale)

FIGURE 10-2



TYPICAL SECTION THRU CONCRETE FLOODWALL
(Not to Scale)

FIGURE 10-3

In designing a levee or floodwall system consideration must be given to protecting the structure from the erosive forces of the tidal waters. A stone apron is often necessary to prevent scouring and undermining of the waterside toe of floodwalls, and the entire seaward face of an earthern levee must be armored with stone to prevent wave damage. During design, consideration must also be given to interior drainage, i.e., providing a means for removing water draining into the landside area of the protection. Generally, either a ponding area and/or a pumping station is provided to avoid flooding from interior drainage.

Because of the high cost of providing this type of protection, the applicability of levees and floodwalls in the Bay Region would generally be limited to those highly developed urbanized areas where there is extensive residential, commercial, or industrial development that is subject to periodic flooding. It should also be noted that providing a levee or floodwall of sufficient height to protect against a major tidal flood could severely restrict the use of the shoreline for recreational or transportation and shipping purposes. Also, the protection may be considered unacceptable from an aesthetic standpoint if the view of the water body is restricted.

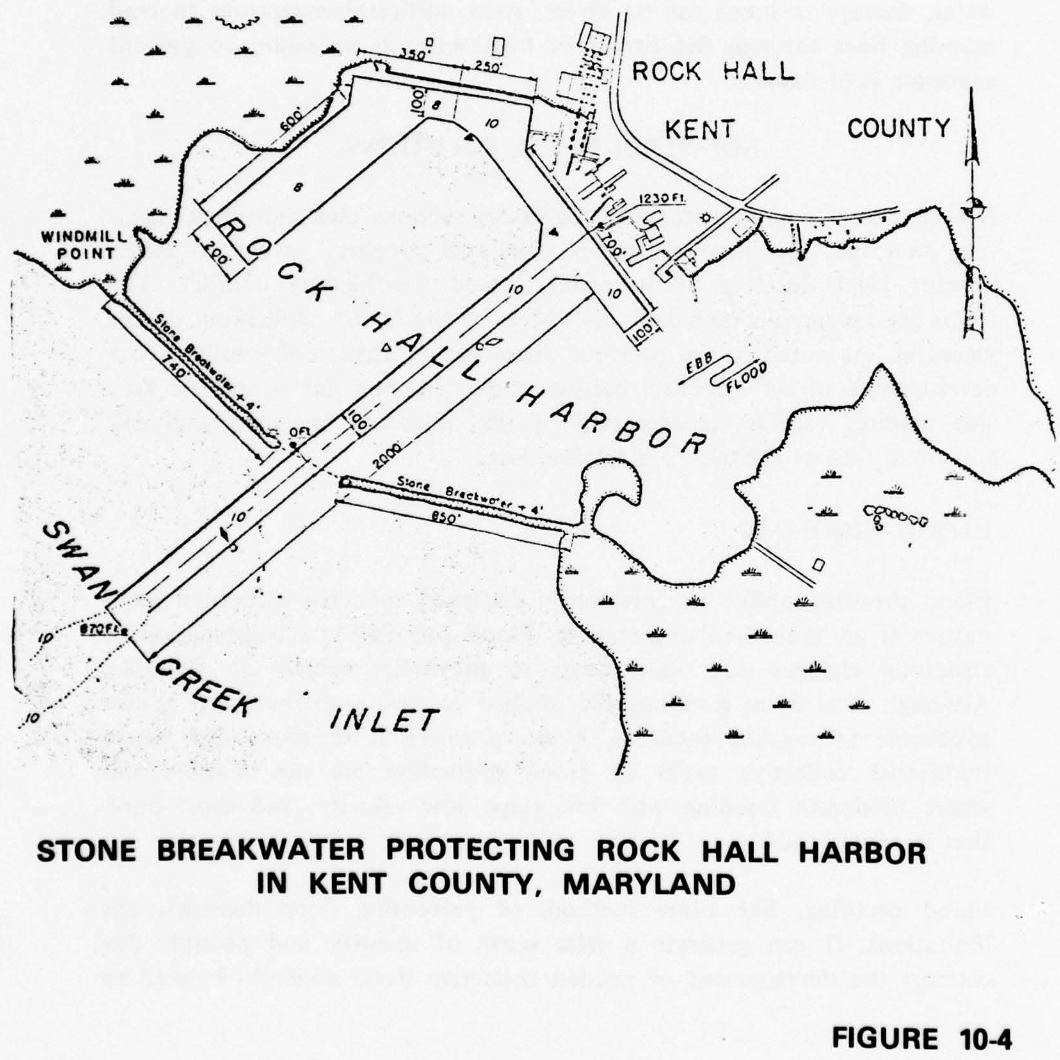
BREAKWATERS

A breakwater is a barrier that is designed to break the force of storm waves and thus reduce the damage that would be experienced by storm waves breaking on shoreline development. Breakwaters are also used to create harbors of refuge that provide safe mooring for recreational and commercial craft. Breakwaters may be either shore connected or located offshore and are generally classified by either the construction materials or the method of construction. The different types of breakwaters include: (1) rubble-mound breakwaters consisting of stone or concrete blocks; (2) composite breakwaters constructed with a stone-asphalt mixture; (3) concrete caisson breakwaters which are reinforced concrete shells filled with stone or sand; (4) cellular sheet-piling breakwaters consisting of steel sheet piling cells filled with sand; (5) timber-crib breakwaters which are timber cribs filled with rubble; and (6) mobile or floating breakwaters which are cells that may be moved into place when a tidal flood is predicted.

The design of an effective breakwater includes consideration of the expected height and direction of storm waves, selection of size and type of construction materials based on expected wave forces, availability of construction materials in the project area, the impact of the breakwater on commercial and recreational boating, and the environmental impact on the biota in the project area.

Some of the more common problems associated with breakwaters include improper selection of the size or type of materials to be used in the construction; flanking through shoreline erosion of the landside end of the breakwater; and the creation of undesirable current patterns in the project area that may affect flushing action, navigation, and littoral transport.

The most common type of breakwater in the Region is the shore connected, rubble-mound breakwater. In the sheltered waters of the Bay and the sub-estuaries this type of protection is very effective and usually can be constructed with materials that are available locally. An example of a rubble-mound breakwater is shown on Figure 10-4.



STONE BREAKWATER PROTECTING ROCK HALL HARBOR IN KENT COUNTY, MARYLAND

FIGURE 10-4

HARBORS OF REFUGE

A substantial amount of the property damage incurred during a tidal flood is wave damage to recreational and commercial craft. Harbors of refuge provide areas of calm water for the safe mooring of all types of craft. Harbors of refuge can be naturally sheltered areas such as coves or inlets or existing marina and mooring areas can be protected through the use of breakwaters as discussed above. In addition to providing a mooring area that is not subject to severe wave action, harbors of refuge must also be designed to provide for the variations in water surface elevation that occur with a storm surge. Unless the pilings and mooring facilities are of sufficient height to permit proper mooring during high water, damage to boats can be severe. Also, sufficient manpower to tend mooring lines through the period of high water is necessary to prevent excessive boat damage.

NON-STRUCTURAL SOLUTIONS

Non-structural solutions include regulatory actions and individual measures that may be adopted by an individual property owner to either prevent tidal flooding or to avoid a land use-flooding conflict. The following paragraphs include a discussion of the broad application of the measures. As noted in the previous discussion of structural solutions, the development of an effective non-structural program for a specific area also requires careful consideration of the numerous environmental and economic factors relative to tidal flooding.

FLOOD PROOFING

Flood proofing unlike the previously discussed collective structural alternatives is an individual undertaking. Flood proofing is a combination of structural changes and adjustments to properties subject to flooding. Although it is more economically applied to new construction it is also applicable to existing facilities. Flood proofing is recommended where traditional collective types of flood protection are not feasible and where moderate flooding with low stage, low velocity, and short duration is experienced.

Flood proofing, like other methods of preventing flood damages, has limitations. It can generate a false sense of security and possibly discourage the development of needed collective flood control. Applied to

structurally inadequate buildings, it can result in more damage than would occur if the building were not flood proofed.

The flood proofing technique also presents certain practical difficulties. A complex pattern of land and building ownership would present problems in cooperation before a community-wide program could be carried out. In addition, retail businesses as well as houses frequently change ownership and this would tend to discourage investments in flood proofing measures. Another complication is the requirement of accurate and timely flood forecasts for successful flood proofing operations. Flood proofing is not a cure for all flood problems. Rather, it should be considered as one device among an array of available flood damage reduction measures.

Flood proofing measures can be classified into three broad types. First, there are permanent measures which become an integral part of the structure. Second, there are standby measures which are used only during floods, but which are constructed or made ready prior to any flood threat. Third, there are emergency measures which are carried out during a flood according to a predetermined plan.

PERMANENT FLOOD PROOFING MEASURES

Permanent measures essentially involve either the elimination of openings *through which water can enter or the reorganization of space within* buildings. Unnecessary doors and windows can be permanently sealed with brick. A watertight flood shield at a doorway opening can also serve as the door. Valves can be installed on basement sewer pipes to prevent flood water from backing up into the basement. Boilers, air conditioning units, and other immobile machinery can be moved to higher elevations and replaced with movable furniture or stock. Adjustments such as these can be most easily undertaken in existing buildings during periods of remodeling or expansion.

From the standpoint of readiness, permanent measures are preferable to other measures and should be incorporated into a flood proofing program to the greatest degree practicable. In many cases, permanent flood proofing does not require an advance flood warning or the availability of special personnel and it provides the greatest measure of safety by reducing the element of human error. Because of the possibility of unforeseen failure, however, some trained personnel should be on hand

in the event of an emergency. At some buildings it may possible to make many permanent changes while at others, few will be possible, if any.

STANDBY MEASURES

In many buildings it is necessary to maintain access into structures at points below selected flood protection levels. In addition, display windows at commercial structures must not be blocked in order to serve their main purpose. These types of openings cannot be permanently flood proofed, but they can be fitted with removable flood shields. Since the placement and installation of such devices requires several hours, a flood warning system has to be established before such flood proofing measures can become operational. Many contingent or standby flood proofing devices have relatively long periods of usefulness—for example, the steel or aluminum flood shields. Building remodeling may alter an opening in such a way that its flood shield is no longer useful, however. In such cases, emergency sandbagging or other temporary measures may be needed. The outmoding of protective measures will be less likely if they are made a part of a building's superstructure and can retract into the ceiling above entrances.

EMERGENCY MEASURES

Emergency measures are carried out during an actual flood experience. These measures may be designed to keep water out of buildings, for example, the sandbagging of entrances or the use of planking covered over with polyethylene sheeting. More often they are intended only to protect equipment and stock. A widely used emergency measure is the planned removal of contents to higher locations when a certain flood stage is reached.

Emergency measures have proven to be an effective means of reducing flood losses, particularly where flood warnings can be issued several days in advance of the water's arrival. At times, emergency measures can include actual construction. In some cases the lower sections of windows and doors have been bricked shut in anticipation of flooding, on other occasions temporary walls and levees have been built to keep flood waters away from structures. In some instances where it was not possible to prevent the entry of flood waters, machinery has been dismantled and taken to sites above flood stages, and large quantities of

stock have been relocated above the reach of flood waters. Emergency measures are generally less effective than permanent or contingent measures because they are more susceptible to carelessness or complacency.

Owners and managers of buildings should be cautioned not to undertake piecemeal flood proofing measures such as installing standpipes or barricading entrances and store windows without professional assistance since such measures could worsen the flood damages.

FLOOD FORECASTING

Reliable and accurate forecasts of floods and flood stages can be coupled with timely evacuation to save lives and reduce property losses. Because of the highly technical nature of the work and the interstate factors that must be considered, the Federal Government has provided leadership in developing and operating the major forecasting system. The Environmental Science Services Administration (U.S. Weather Bureau) has the primary responsibility, although other Federal and State agencies such as the Corps of Engineers, Bureau of Reclamation, and Tennessee Valley Authority cooperate in providing services in selected areas. There are many areas for which forecasts are not available; and too few cities and communities have adequate plans to effectively utilize this information.

The National Weather Service office in Washington, D.C. issues weather bulletins for the Bay Area. This information based on forecasts by the U.S. Weather Bureau is disseminated by teletype to the local television and radio stations, and newspapers. If conditions warrant abandonment of residence in low lying areas, the offices of Civil Defense and Red Cross will conduct the evacuation and set up temporary accommodations at area schools, churches, and available government installations.

EVACUATION

Evacuation of an area that is subject to flooding can be either temporary or permanent in nature. Temporary evacuation takes place after it is known that a flood can be expected and includes such measures as moving people and materials to higher ground and taking other appropriate flood fighting and relief measures. Permanent evacuation involves the acquisition of lands and improvements that are subject to flooding and the relocation of people into flood free areas. Flood plain lands

that are acquired can then be converted to recreational use, green space or other uses that will not incur significant damages from a flood occurrence.

LAND USE CONTROLS

Land use controls, most often known as "Flood Plain Regulations," do not attempt to reduce or eliminate flooding but are designed to mold the flood-plain development in such a manner as to lessen the damaging effects of floods. Flood-plain regulations imply the adoption and use of legal tools, to control the extent and type of future development in flood prone areas. For these controls to be effective, it is necessary that the public understand the general flood problem, the degree of risk, and the methods that can be used to control use of the land. There are various means of effecting such flood-plain management.

ZONING

Zoning is the legal tool that is used to implement and enforce the detailed plans resulting from a flood plain management program. Zoning is used by towns, cities, counties, and agencies of the State to control and direct the use and development of land and property within their jurisdiction. Zoning insures the safekeeping of property for the public health and welfare and the best use of available land. The division of communities into various flood zones should be the result of a comprehensive flood plain management program for the entire area. Designated floodways may be zoned for the purpose of passing floodwaters and for other limited uses that do not conflict with that primary purpose. The ordinance may also establish regulations for the flood-plain areas outside the floodway. These regulations may also include designating elevations below which certain types of development cannot be constructed.

SUBDIVISION REGULATIONS

A subdivision can be defined in a broad sense as a tract of land divided into lots for the purpose of sale or building development. Subdivision regulations are used by local governments to specify the manner in which land may be divided. They may state the required width of streets, requirements for curbs and gutters, size of lots, elevation of land, freedom from flooding, size of floodways, and other points pertinent to the welfare of the community. Not only can public health and

welfare benefit, but various municipal costs such as maintenance of streets and utilities can be reduced during flood periods. Subdivision regulations provide an efficient means of controlling construction in presently undeveloped flood-plain areas. The following typical provisions which could be added to regulations would be helpful to flood damage prevention:

a. Show extent of the flood plain on subdivison maps;

b. Show floodway limits or encroachment lines;

c. Prohibit fill in channels and floodways that would restrict flow;

d. Require that stormwater runoff be controlled for the entire subdivision;

e. Require that subdivision roads be above the elevation of a selected flood level;

f. Require that each lot contain a building site with an elevation above a selected flood level.

BUILDING CODES

Building codes are a set of standards for the construction of buildings. These codes establish specifications for minimum protection elevations through flood proofing or the raising of structures. Development of building codes should include a study of flood plain regulations, geographic factors affecting decisions to occupy the flood plain, and the evaluation of nonstructural measures of flood abatement. A well-written and properly enforced building code can effectively reduce damages to buildings in the flood plain. Several of the requirements which should be specified in a building code to reduce flood damages are:

a. Prevent flotation of buildings from their foundations by requiring proper anchorage;

b. Establish basement elevations and minimum first floor elevations consistent with potential floods;

c. Require structural strength to withstand water pressure or high velocity of flowing water;

d. Restrict the use of materials which deteriorate rapidly when exposed to water;

e. Prohibit equipment that might be hazardous to life when submerged, such as chemical storage, boilers, or electrical equipment.

So far few communities have developed building codes which take potential flood risks into account. The flood-proofing standards which most cities have adopted establish a minimum protection elevation for the first floors and utilities. Sometimes flood-proofing requirements are placed in flood-plain zoning ordinances in the form of general performance standards. This gives the developer the option of flood proofing the structure to a safe height or elevating the structure above designated flood heights.

FLOOD INSURANCE

As noted in Chapter 2 of this appendix, the National Flood Insurance Program was enacted as a means of making flood insurance available to eligible communities at reasonable rates through a joint Government-industry program. In order to qualify for the insurance, communities must adopt certain land use and control measures to reduce or avoid flooding in connection with future construction in the flood plain. In order for flood insurance tto be effective, insurance rates should realistically reflect the flood risk in order to avoid improper development of the flood plain. As noted on Table 10-8, the majority of the counties and local jurisdictions in the Region are enrolled in the Flood Insurance Program.

PUBLIC AWARENESS PROGRAMS

The potential hazards of tidal flooding are sometimes not evident to a prospective developer or homeowner. In other instances, the hazard may be apparent; but the preventative action taken to avoid the problem is either ill-conceived or constructed. In either case, the individual would benefit from additional information relative to tidal flooding.

A public awareness program would serve to advise the public as to the location of the flood plain and expected flood heights. The program could also provide information as to the structural and nonstructural measures that could be used to control tidal flooding. The success of a public awareness program that is directed toward "self-help" is highly dependent on the publicity which it receives. Distribution of information should be supplemented by public meetings to explain the purpose and intent of the program and where further technical advice can be secured.

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CHAPTER V

REQUIRED FUTURE STUDIES

Based on the discussion and analysis of the existing and future tidal flooding problems included in the previous chapters, it is apparent that a comprehensive Bay-wide flood management and control plan is an important part of any total management plan for Chesapeake Bay. The development of that flood plan and the assessment of its impacts on both the Bay and its resources is a considerable undertaking that requires analytical and field studies as well as testing on the Chesapeake Bay Hydraulic Model.

The development of a Bay-wide flood plan requires a better understanding of both the existing and potential flood threat. The tidal surge and the wave set-up that are generated as storm systems of varying intensities move through the Region must be better defined. Given the expected flood elevations, an extensive program of flood plain delineation is required to define the area that is inundated by floods of varying frequencies. Combined with the above flood plain delineation and stage-frequency analyses should be a determination of the dollar damage that can be expected from varying flood heights. With the existing and potential flood threat better defined through the above studies, structural and non-structural solutions can be formulated to solve the tidal flood problems.

The applicability of various structural and non-structural solutions to tidal flood problems in the Bay also requires additional study. For example, some non-structural solutions such as flood proofing must be evaluated as to their feasibility where wave action is expected to be severe. The development of a comprehensive Bay-wide flood warning and evacuation system also requires considerable study to define such parameters as expected warning times, evacuation routes and areas of responsibility.

Equally important to the development of a plan is an assessment of the environmental impacts of proposed structural and non-structural control measures. To aid in environmental assessments, studies are required to better define the impact that structural measures such as flood walls and breakwaters have on water quality and the Bay biota. The economic-social impacts of such measures as evacuation also need to be explored.

The Chesapeake Bay Hydraulic Model has the potential to provide some of the physical data that is necessary to define the tidal flood problem and evaluate the effects of flood control measures. The model can be used to define the elevation and thus the area inundated by various storm surges. It should be noted that because the model is distorted, i.e., the vertical and horizontal scales are not the same, the wave action associated with major storms cannot be duplicated; however, analytical studies can be used to predict the wave set-up that accompanies the tidal surge. As part of this same type of test, the magnitude and direction of tidal currents associated with storm surges may also be recorded. Information on tidal currents would be valuable in defining areas subject to severe erosive forces and locations where severe currents may cause ship handling problems. With the existing flood conditions defined, the model could then be used to evaluate the physical effects of proposed structural flood control measures. For example, changes in tidal current patterns that would result from construction of a breakwater could be determined.

Similar to evaluating flood control structures, the model can also be used to access the impact, as it relates to tidal flooding, of other structural proposals. Major channel improvements, groin fields, and large diked disposal areas are just several examples of projects that could be evaluated from the standpoint of their effects on tidal flooding. A more detailed discussion of the capabilities of the hydraulic model and examples of the tests that can be conducted may be found in Appendix 16, Hydraulic Model Testing.

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FLOOD CONTROL
GLOSSARY

bay:	A recess in the shore or an inlet of a sea between two capes or headlands, not as large as a gulf but larger than a cove.
beach:	The zone of unconsolidated material that extends landward from the mean low water line–unless otherwise specified–to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation.
breakwater:	A structure protecting a shore area, harbor, anchorage, or basin from waves.
bulkhead:	A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.
channel:	(1) A natural or artificial waterway of perceptible extent which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. (2) The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation. (3) The deepest part of a stream, bay, or strait, through which the main volume or current of water flows.
coast:	A strip of land of indefinite width (may be several miles) that extends from the shoreline inland to the first major change in terrain features.
coastal zone:	The land and sea area bordering the shoreline.
coastal plain:	The plain composed of horizontal or gently sloping strata of fragmented older rock materials fronting the coast, and generally representing a strip of sea bottom that has emerged from the sea in recent geologic time.

design hurricane: A representation of a hurricane with specified characteristics that would produce hurricane surge hydrographs and coincident wave effects at various key locations along a proposed project alinement. It governs the project design after economics and other factors have been duly considered.

dike: A wall or mound built around a low-lying area to prevent flooding.

dunes: Ridges or mounds of loose, wind-blown material, usually sand.

estuary: (1) That portion of a stream or river influenced by the tide of the body of water into which it flows. (2) A bay, as the mouth of a river, where the tide meets the river current.

extratropical storm: See Northeaster.

ecology: The study of the interrelationships of organisms with and within their environment.

ecosystem: A community and its (living and non-living) environment considered collectively; the fundamental unit of ecology.

fetch: The area in which seas are generated by a wind having a rather constant direction and speed. Sometimes used synonymously with fetch length.

fetch length: The horizontal distance (in the direction of the wind) over which a wind generates seas or creates wind setup.

flood: An overflow of lands not normally covered by water and that are used or are usable by man. Floods have two essential characteristics: the inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river or

	stream or an ocean, bay, or other body of standing water.
flood plain:	The relatively flat area or low lands adjoining the channel of a river, stream or watercourse or ocean, bay, or other body of standing water, which has been or may be covered by flood water.
flood stage:	The stage or elevation at which overflow of natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.
floodwall:	A structure built along a water course to prevent flooding in the adjacent land area. Primarily used where levees are not feasible, either due to space limitations or considerable wave action. See Seawall.
fluvial:	That which is produced by a river.
harbor:	Any protected water area affording a place of safety for vessels. See also Port and Refuge Harbor.
hurricane:	An intense tropical cyclone in which winds tend to spiral inward toward a core of low pressure, with maximum surface wind velocities that equal or exceed 75 mph (65 knots) for several minutes or longer at some points. Tropical Storm is the term applied if maximum winds are less than 75 mph.
hydraulic model:	A flow system so operated that the characteristics of another similar system may be predicted. A model is generally a small-scale reproduction of the prototype, but may be larger and/or geometrically distorted.
hydrodynamics:	The study of the motion of and the forces acting on water.

hydrology:	The scientific study of the waters of the earth, especially with relation to the effects of precipitation and evaporation upon the occurrence and character of water in streams, lakes, and on or below the land surface.
intermediate regional tidal flood:	A tide having an average frequency of occurrence in the order of once in 100 years although the tide may occur in any year. It is based on statistical analyses of tide records available for the "general region of the study area."
levee:	A dike or embankment to protect land from inundation.
marina:	A boat basin offering dockage and other service of small craft, usually recreational craft.
mean low water (mlw):	The average height of the low waters over a long period of time.
mean sea level (msl):	A fixed reference plain determined by the United States Coast and Geodetic Survey. Mean sea level as used herein is based on the latest sea level datum adjustments of 1953, 1955, and 1959, and approximately the average level of the sea for all stages of the tide over a long period of time.
northeaster:	A cyclonic type storm which develops near the Atlantic Coast and is most common during the winter months and early spring. Wind speeds are not as great and central pressures are not as low as ordinary hurricanes, but winds cover a considerably greater area.
port:	A place where vessels may discharge or receive cargo; may be the entire harbor including its approaches, or may be the commercial part of a harbor where the wharves and facilities for transfer of cargo, docks, and repair shops are situated.

refuge harbor:	A naturally or artifically enclosed or nearly enclosed harbor area which provides small craft safety from storm conditions.
riprap:	A layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also the stone so used.
runup:	The rush of water up a structure or beach on the breaking of a wave. The amount of runup is the vertical height above stillwater level that the rush of water reaches.
scour:	Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.
seawall:	A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. See Also Bulkhead and Floodwall.
sheet piling:	A group of piles with a generally slender flat cross section to be driven into the ground or seabed and meshed or interlocked with like members to form a diaphragm, wall, or bulkhead.
shore:	The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach.
shoreline:	The intersection of a specified plane of water with the shore or beach (e.g., the highwater shoreline would be the intersection of the plane of mean high water with the shore or beach). The line delineating the shoreline on U.S. Coast and Geodetic Survey nautical charts and surveys approximates the mean high water line.

standard project tidal flood:	The flood in coastal areas caused by a storm surge that may be expected from the more severe combinations of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Such floods, as used by the Corps of Engineers, are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous.
storm surge:	A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress. See Wind Setup.
tide:	The periodic rising and falling of the water that results from gravitational attraction of the moon and sun and other astronomical bodies acting upon the rotating earth.
tidal station (guage):	A place at which tide observations are being taken. It is called a primary tide station when continuous observations are to be taken over a number of years to obtain basic tidal data for the locality. A secondary tide station is one operated over a short period of time to obtain data for a specific purpose.
topography:	The configuration of a surface, including its relief, the position of its streams, roads, building, etc.
tributary:	A stream or other body of water that contributes its water to another and larger stream or body of water.
tropical cyclone:	See Hurricane.

tropical disturbance:	A cyclonic wind storm of tropical origin with winds less than 39 mph.
tropical storm:	A cyclonic wind storm of tropical origin with winds from 39 to 74 mph.
wind setup:	(1) The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water. (2) The difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water. (3) Synonymous with Storm Surge. Storm Surge is usually reserved for use on the ocean and large bodies of water. Wind Setup is usually reserved for use on reservoirs and smaller bodies of water.
wind waves:	(1) Waves being formed and built up by the wind. (2) Loosely, any wave generated by wind.

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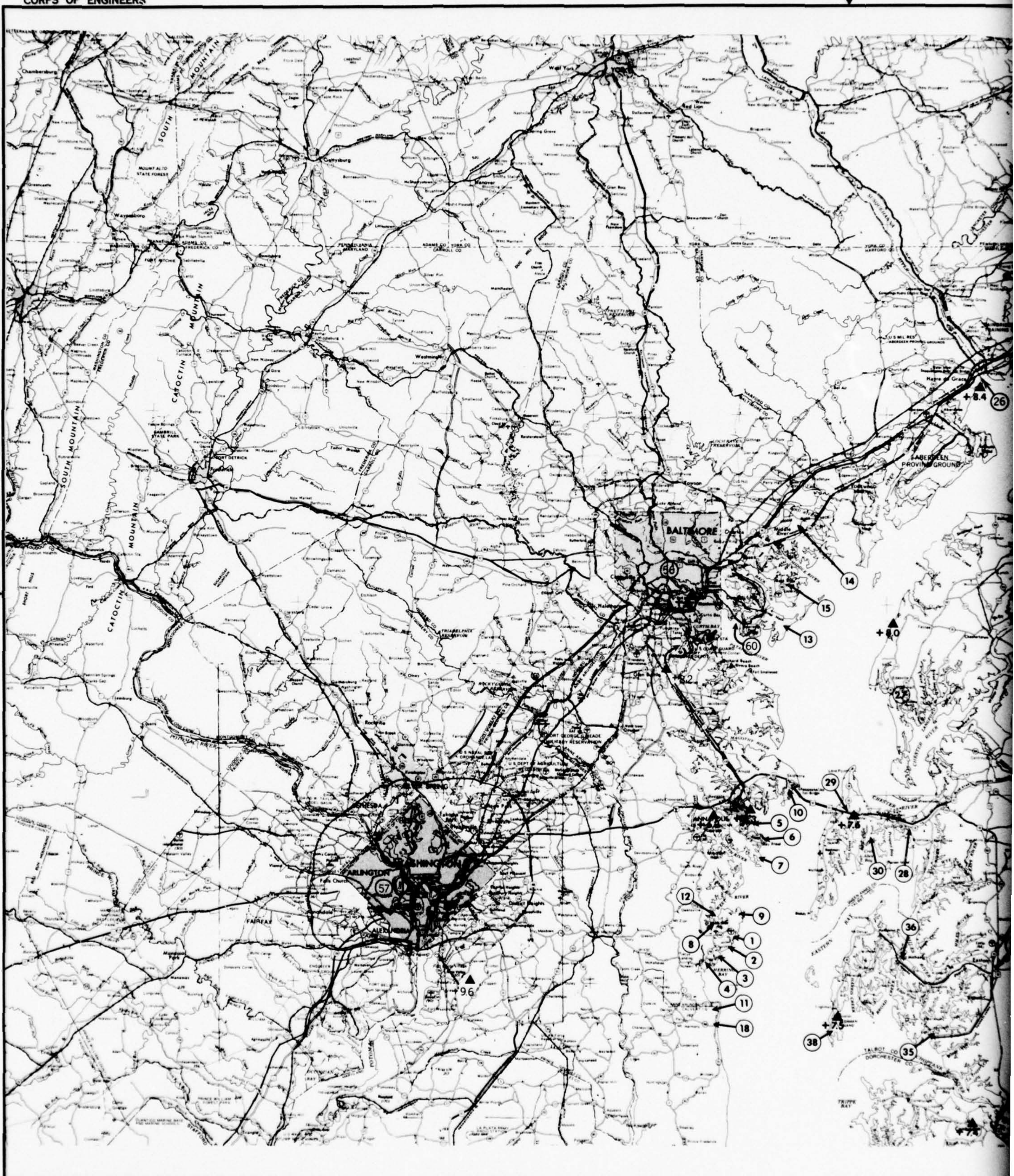


U. S. ARMY

▲ Elevation in Feet Above Mean Sea Level Of The 100-Year Flood At An Established Tidal Bench Mark

○ Areas Subject To Tidal Flooding Numbers Are Keyed To Table 10-5

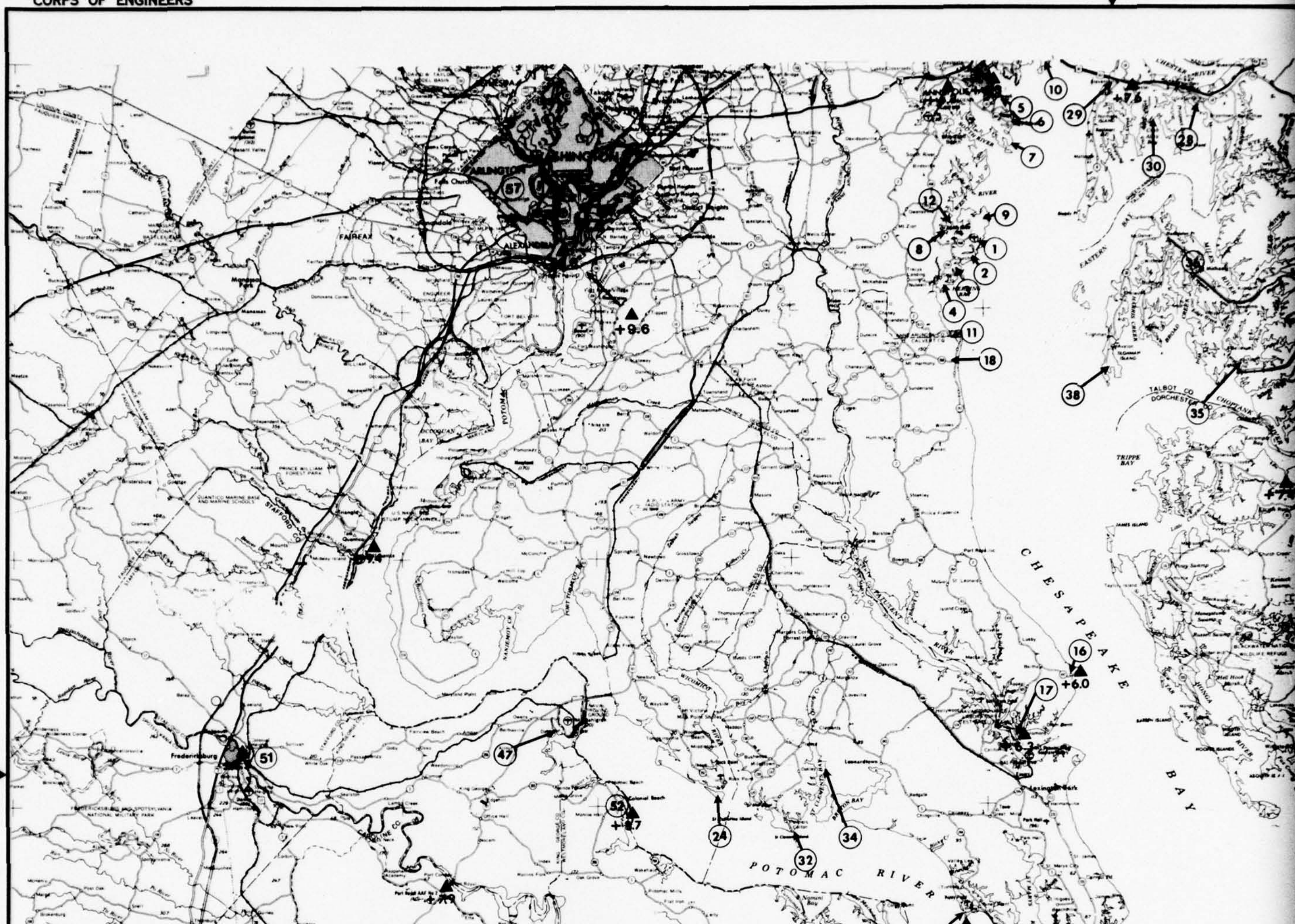
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

CHESAPEAKE BAY STUDY
FUTURE CONDITIONS REPORT

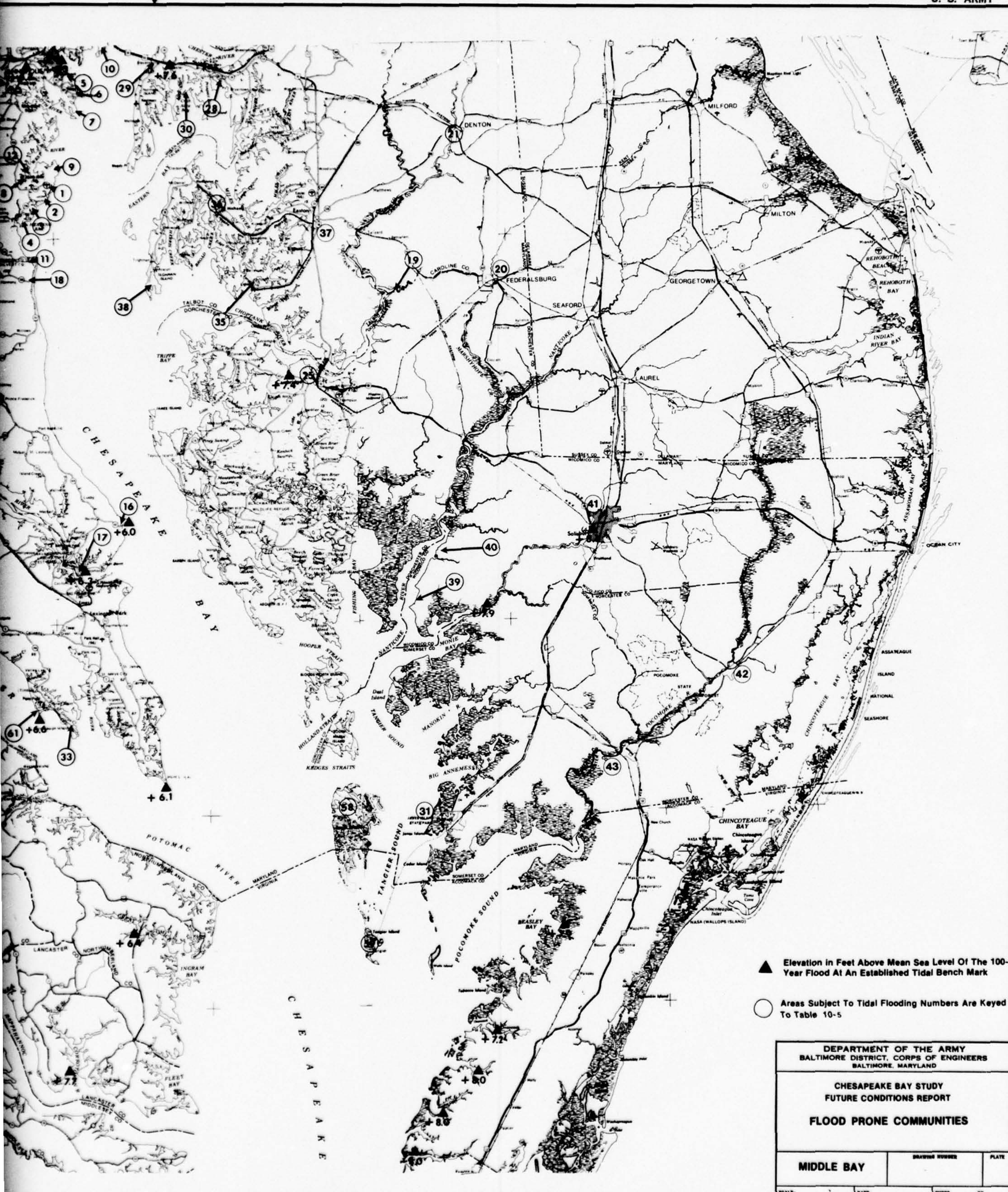
FLOOD PRONE COMMUNITIES

UPPER BAY	DRAWING NUMBER	PLATE
SCALE:	DATE:	SHEET OF

PLATE 10-1


CHESAPEAKE BAY
POTOMAC RIVER
POTOMAC RIVER
Fredericksburg
RICHMOND
CAROLINE CO
KING & QUEEN CO
RICHMOND CO
ESSEX CO
KING WILLIAM CO
LANCASTER
NORTHUMBERLAND CO
LANCASTER MIDDLESEX CO
INGRAM BAY
FLEET BAY
TRIPPE BAY
TALBOT CO DORCHESTER
CAMP AP HILL
FAIRFAX
+9.6
+6.0
+6.1
+6.6
+7.6
+8.0
+6.4
+7.7

U. S. ARMY



▲ Elevation In Feet Above Mean Sea Level Of The 100-Year Flood At An Established Tidal Bench Mark

○ Areas Subject To Tidal Flooding Numbers Are Keyed To Table 10-5

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

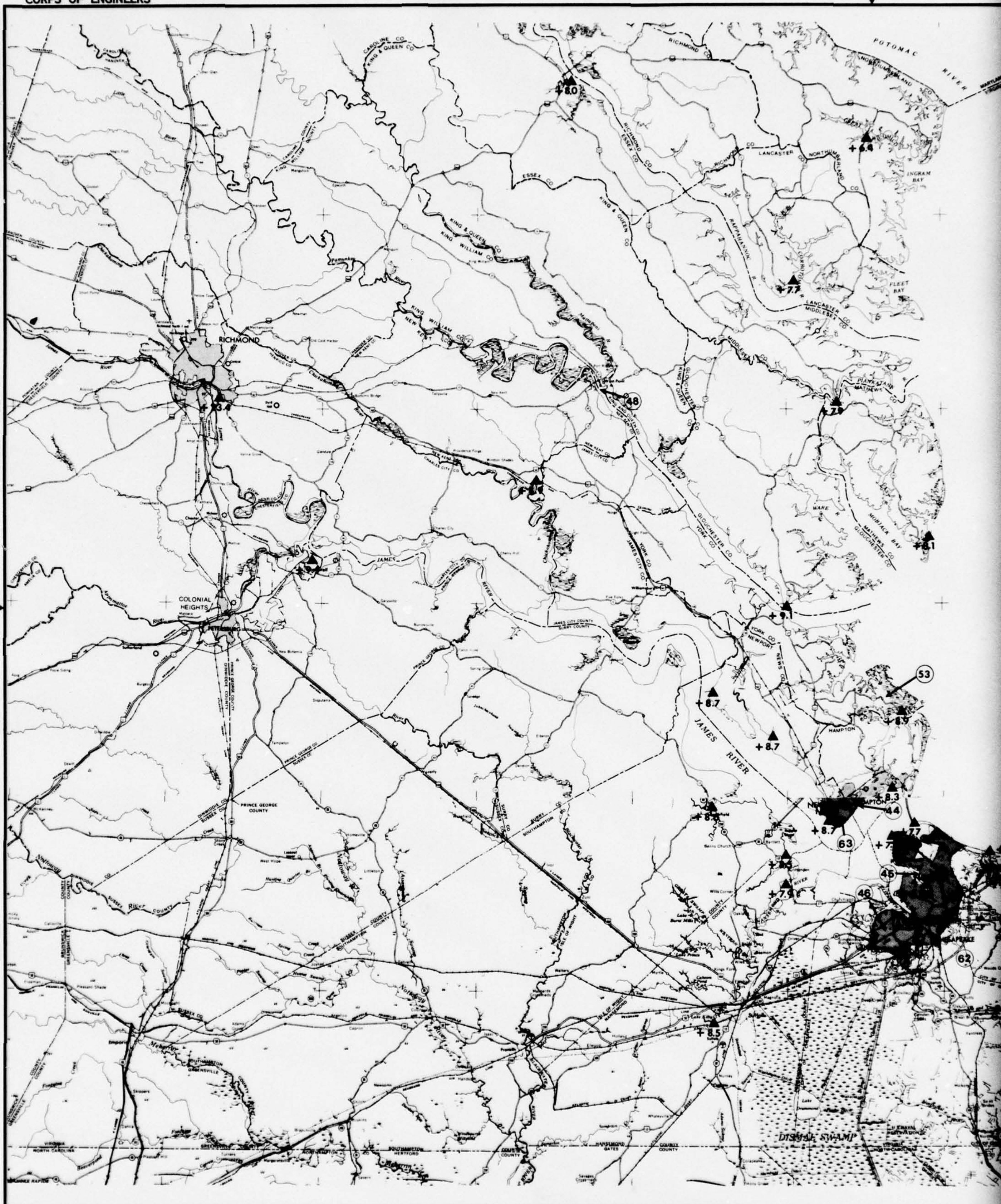
CHESAPEAKE BAY STUDY
FUTURE CONDITIONS REPORT

FLOOD PRONE COMMUNITIES

MIDDLE BAY	DRAWING NUMBER	PLATE
SCALE:	DATE:	SHEET OF

PLATE 10-2

CORPS OF ENGINEERS



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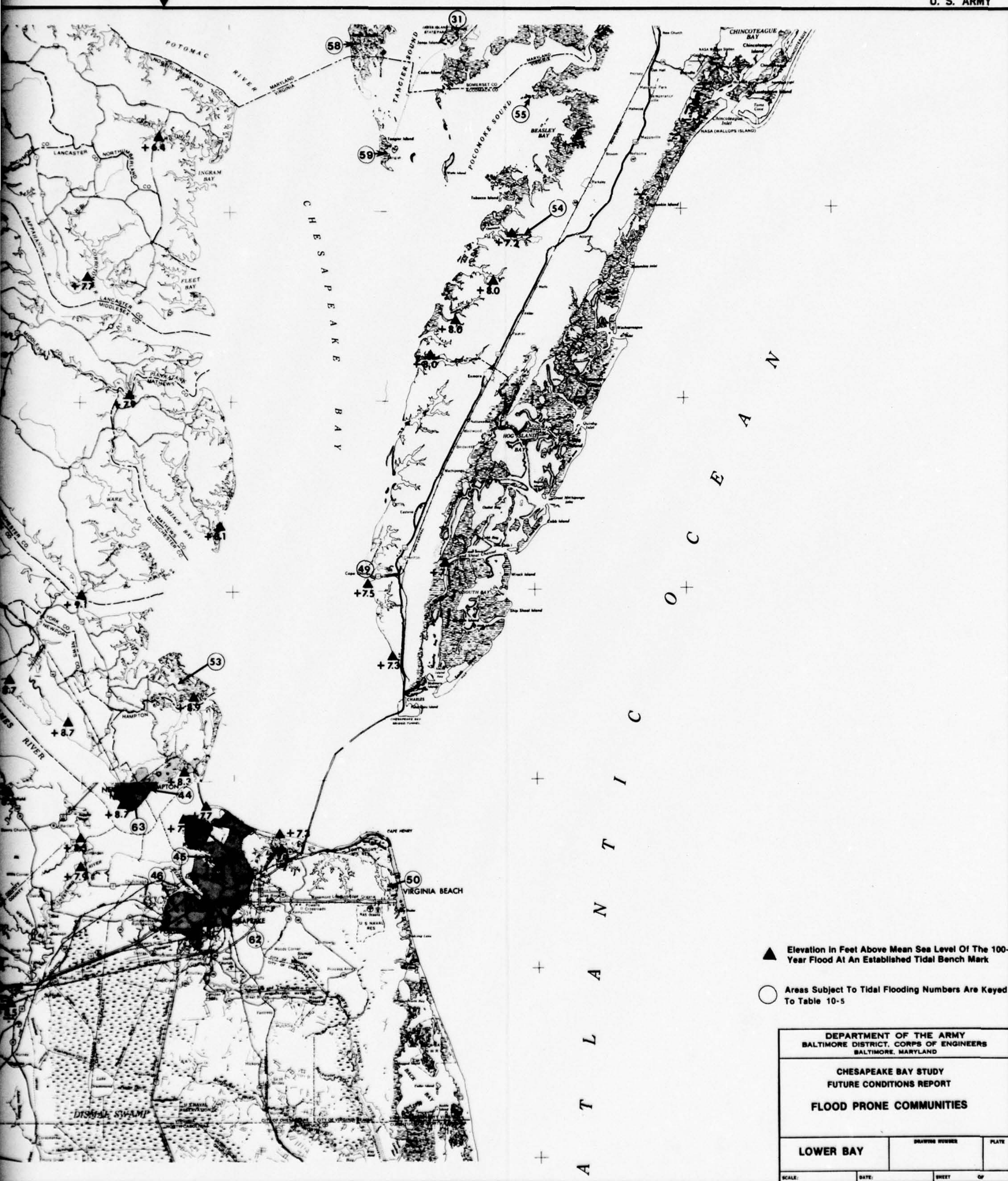

PLATE 10-3

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CHESAPEAKE BAY FUTURE CONDITIONS REPORT

APPENDIX 11

SHORELINE EROSION

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CHAPTER I

THE STUDY AND THE REPORT

The Chesapeake Bay Study evolved through the need for a complete and comprehensive investigation of the use and control of the water resources of the Bay Area. In the first phase of the Study, the existing physical, biological, economic, social, and environmental conditions and problem areas were identified and presented in the *Existing Conditions Report.* The *Future Conditions Report,* of which this appendix is a part, presents the findings of the second or projections phase of the Study. Included as part of the second phase are the projections of future water resource needs and problem areas, identification of general means that might best be used to satisfy those needs, and recommendations for future studies and hydraulic model testing. The results of this phase of the Study and this report constitute the next step toward the goal of developing a comprehensive water resource management program for Chesapeake Bay.

Chesapeake Bay is a vast natural resource. Along with its tributaries, the Bay provides a natural transportation network on which the economic development of the Region has been based, a wide variety of water-oriented recreational opportunities, a home for numerous fish and wildlife, a source of water supply for both municipalities and industries, and the site for final disposal of our waste products. All of the resources provided by the Bay interact with each other in forming the Chesapeake Bay Ecosystem. Unfortunately, problems often arise when man's intended use of one resource conflicts with either the natural environment or man's use of another resource.

Because of the many resources that the Bay has to offer, extensive development has occurred along its shoreline. Because the transportation network offered by the Bay, cities developed along many of the subestuaries and shipping and handling facilities and related industry were located along the shoreline. The increased demand for waterfront home sites in recent years has also accounted for widespread development. Conflicts arise when development occurs along shorelines that are subject to severe erosion. This particular volume, "Shoreline Erosion," will focus on these conflict areas. Appendix 11 focuses on shoreline erosion. An assessment of areas presently affected by erosion as well as areas where projected development may be threatened by erosion is addressed ~~in this appendix~~. Recommendations are made for preventing and/or reducing shoreline erosion, and the future studies that are required to develop a comprehensive shoreline erosion management program for Chesapeake Bay are identified.

AUTHORITY

The authority for the Chesapeake Bay Study and the construction of the hydraulic model is contained in Section 312 of the River and Harbor Act of 1965, adopted 27 October 1965, which reads as follows:

> (a) The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a complete investigation and study of water utilization and control of the Chesapeake Bay Basin, including the waters of the Baltimore Harbor and including, but not limited to, the following: navigation, fisheries, flood control, control of noxious weeds, water pollution, water quality control, beach erosion, and recreation. In order to carry out the purposes of this section, the Secretary, acting through the Chief of Engineers, shall construct, operate, and maintain in the State of Maryland a hydraulic model of the Chesapeake Bay Basin and associated technical center, Such model and center may be utilized, subject to such terms and conditions as the Secretary deems necessary, by any department, agency, or instrumentality of the Federal Government or of the States of Maryland, Virginia, and Pennsylvania, in connection with any research, investigation, or study being carried on by them of any aspects of the Chesapeake Bay Basin. The study authorized by this section shall be given priority.
>
> (b) There is authorized to be appropriated not to exceed \$6,000,000 to carry out this section.

An additional appropriation for the study was provided in Section 3 of the River Basin Monetary Authorization Act of 1970, adopted 19 June 1970, in which reads as follows:

> In addition to the previous authorization, the completion of the Chesapeake Bay Basin Comprehensive Study, Maryland, Virginia, and Pennsylvania, authorized by the River and Harbor Act of 1965 is hereby authorized at an estimated cost of \$9,000,000.

As a result of Tropical Storm Agnes, which caused extensive damage in Chesapeake Bay, Public Law 92-607, the Supplemental Appropriation Act of 1973, signed by the President on 31 December 1972, included \$275,000 for additional studies of the impact of the storm on Chesapeake Bay.

PURPOSE

Previously, measures taken to utilize and control the water and land resources of the Chesapeake Bay Basin have generally been oriented toward solving individual problems. The Chesapeake Bay Study provides a comprehensive study of the entire Bay Area in order that the most beneficial use be made of the water-related resources. The major objectives of the Study are to:

a. Assess the existing physical, chemical, biological, economic, and environmental conditions of Chesapeake Bay and its water resources.
b. Project the future water resources needs of Chesapeake Bay to the year 2020.
c. Formulate and recommend solutions to priority problems using the Chesapeake Bay Hydraulic Model.

The *Chesapeake Bay Existing Conditions Report,* published in 1973, met the first objective of the Study by presenting a detailed inventory of the Chesapeake Bay and its water resources. Divided into a summary and four appendixes, the report presented an overview of the Bay Area and the economy; a survey of the Bay's land resources and its use; and a description of the Bay's life forms and hydrodynamics.

The purpose of the *Future Conditions Report* is to provide a format for presenting the findings of the Chesapeake Bay Study. Satisfying the second objective of the Study, the report describes the present use of the resource, presents the demands to be placed on the resource to the year 2020, assesses the ability of the resource to meet future demands, and identifies additional studies required to develop a management plan for Chesapeake Bay.

SCOPE

The scope of the Chesapeake Bay Study and *Future Conditions Report* includes the multi-diciplinary fields of engineering and the social, physical, and biological sciences. The Study is being coordinated with all Federal, State, and local agencies having an interest in Chesapeake Bay. Each resource category presented in the *Future Conditions Report* projects demands and potential problem areas to the year 2020. All conclusions are based on historical information supplied by the preparing agencies having expertise in that field. In addition, the basic assumptions and methodologies are quantified for accuracy in the sensitivity section. Only general means to satisfy the projected resource needs are presented, as specific recommendations are beyond the scope of this report.

As shown on Figure 11-1, the geographical area considered in the overall study encompasses those counties or Standard Metropolitan Statistical Areas (SMSA) which touch or have a major influence on the Estuary. For purposes of projecting the future demands on the resources of the Bay, economic and demographic projections were made for all subregions and SMSA's within the Study Area. Regarding shoreline erosion, however, the actual Study Area included only that shoreline area along the Bay and tributaries which is influenced by tidal action.

SUPPORTING STUDIES

This appendix was prepared and coordinated by the Baltimore District, Corps of Engineers. Much of the information included in this report was taken from other sources. The initial data base for this particular volume, as well as all other volumes of this report, was presented in the *Chesapeake Bay Existing Conditions Report.* Other studies that provided a major input to this appendix include the *National Shoreline Study Regional Inventory Report* prepared by the Corps of Engineers; shore erosion studies conducted by the Maryland Geological Survey and published in *Shore Erosion in Tidewater Maryland;* and a report prepared by the Virginia Institute of Marine Science titled *Shoreline Erosion in Tidewater Virginia.* All materials and data used in the appendix are referenced in the Bibliography.

STUDY PARTICIPATION AND COORDINATION

Due to the wide scope, large geographical area, and many resources covered by the Chesapeake Bay Study, data input was required from many sources. Various Federal, State, and local agencies throughout the Bay Region have customarily developed expertise in certain areas of water resource development. Although overall coordination of the Study effort was provided by the Corps of Engineers, input from these various sources was required in order to obtain the best Study coordination and problem identification. Therefore, an Advisory Group and a Steering Committee were established. Five Task Groups were also formed to guide preparation of reports on related resource categories. They are:

1. Economic Projection Task Group
2. Water Quality and Supply, Waste Treatment, Noxious Weeds Task Group
3. Flood Control, Navigation, Erosion, Fisheries Task Group
4. Recreation Task Group
5. Fish and Wildlife Coordination Group

Detailed information on the composition of each Task Group as well as members of the Advisory Group and Steering Committee is presented in the Chesapeake Bay Plan of Study and in Appendix 1, "Study Organization, Coordination, and History."

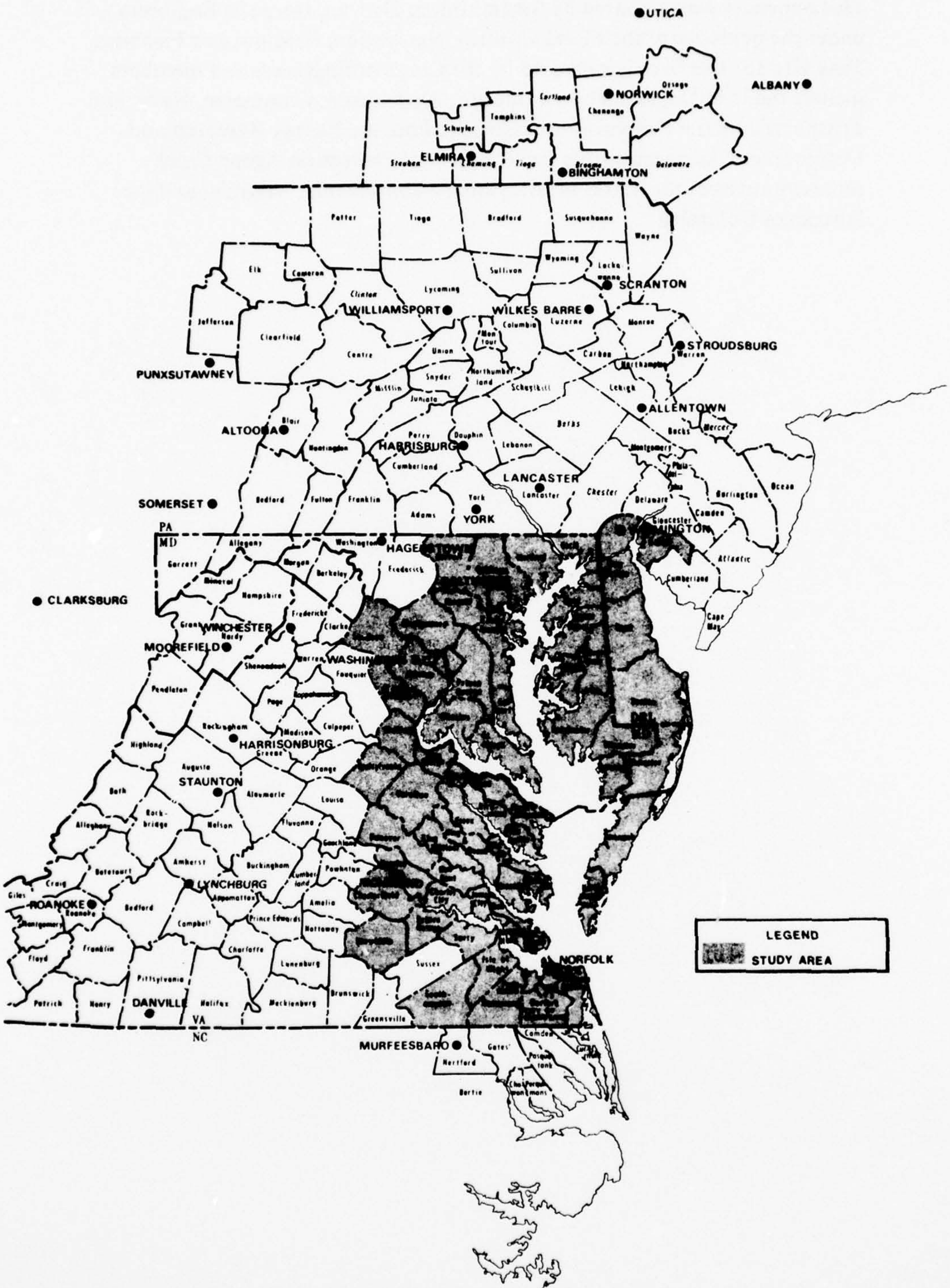


FIGURE 11-1: Chesapeake Bay Study Area

This appendix was prepared by the Baltimore District, Corps of Engineers under the guidance of the Flood Control, Navigation, Erosion, and Fisheries Task Group. The Group is chaired by the Corps of Engineers and members include the U.S. Departments of Interior, Agriculture, Commerce, Navy, and Trnsportation; the Federal Power Commission; the Energy Research and Development Administration; Environmental Protection Agency; and representatives of the States of Maryland, Pennsylvania, Virginia, and the District of Columbia.

CHAPTER II

SHORELINE EROSION IN CHESAPEAKE BAY

This chapter includes a discussion of the impact that shoreline erosion has on the resources of Chesapeake Bay and delineates areas of critical concern. A discussion of the shoreline erosion process and a history of shoreline erosion along Chesapeake Bay is also included to provide a better understanding of the seriousness and complexity of the problem.

DESCRIPTION OF REGION

Chesapeake Bay is one of the largest estuaries in the United States having a surface area of about 4400 square miles and a length of nearly 200 miles. The width of the Bay varies from 4 miles to about 30 miles near the Maryland-Virginia boundary. The Bay receives freshwater from a drainage area of 64,160 square miles with the Susquehanna, Potomac, Rappahannock, York, and James Rivers, providing approximately 90 percent of the total freshwater flow into the Bay. The many major and minor tributaries often extend miles inland, and together with the Bay have a total shoreline of 7300 miles which is subject to erosion.

Chesapeake Bay, as is typical of most Coastal Plain estuaries, is relatively shallow having a mean depth of less than 28 feet. The geologic features and topography of the Region make the Bay and its tributaries highly susceptible to the process of erosion and subsequent sedimentation. On a long term basis, the natural sedimentation processes are tending to fill the Bay and convert it to a riverine system.

The Bay lies entirely within the Coastal Plain which is characterized by poorly consolidated marine and fluvial sediments. The composition and consolidation of the material along the shoreline is one of the most important parameters relative to shoreline erosion. For example, fine-grained consolidated sediments generally erode more slowly than coarse-grained unconsolidated sediments. The flat, low-lying, shoreline of the Bay's Eastern Shore is composed of weakly compacted sands and clays which lack the interparticle cohesion to withstand both normal and storm-induced wave action. The Western Shore consists of more rolling terrain with bank heights up to approximately 150 feet. These higher Western Shore banks are more commonly composed of coarser-grained sediments and are susceptible to erosion by wave induced undercutting and subsequent sluffing of bank material.

The Chesapeake Bay Study Area is characterized by a generally moderate climate with an average temperature of 57 degrees Fahrenheit. The average annual precipitation is approximately 44 incles. Storms in the region are normally one of three types: (1) large area extratropical storms or "lows" which move eastward across the United States, (2) tropical storms or hurricanes that originate in the South Atlantic or Caribbean and move northward through the eastern part of the United States, and (3) local thunderstorms that usually affect a relatively small area. The precipitation and the resultant runoff from these storms contribute significantly to the erosion of the shoreline. Also, the winds that accompany these storms often generate waves that can cause significant shoreline erosion.

Development in the Bay Region has generally occurred along the Bay's tidal tributaries which provided natural transportation routes for waterborne commerce. The largest metropolitan areas are located on the Western Shore and include Baltimore, Maryland; Washington, D.C.; Richmond, Virginia; and Norfolk-Portsmouth, Virginia. These four metropolitan areas contained approximately 80 percent of the inhabitants of the Bay Region in 1970. As indicated above, a large part of the past and present development in the Region is centered around port-related activities which by their very nature are located in areas that may be subject to shoreline erosion. Because of the recreational and aesthetic values of the Bay, many Bay residents have either permanent or second homes located along the Bay shoreline and as such may also suffer damage from erosive forces.

THE SHORELINE EROSION PROCESS

As shown in Figure 11-2, developed by the Virginia Institute of Marine Sciences, the shorelands of Chesapeake Bay are composed of three physiographic elements–fastland, shore, and nearshore. The fastland is that area landward of normal water levels. The shore is the zone of beaches and wetlands which serve as a buffer between the water body and the fastland. Lastly, the nearshore extends waterward from the mean low water level to the 12-foot depth contour. In the Chesapeake Bay proper, the nearshore is generally comprised of a shallow water belt more than 1,000 feet wide before the 12-foot depth contour is encountered. From the 12-foot contour outward, the depth increases at a more rapid rate.

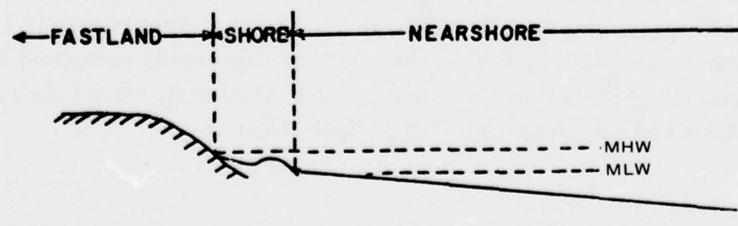


FIGURE 11-2: SHORELANDS OF CHESAPEAKE BAY

While the causes of shoreline erosion are complex and not completely understood, the primary processes responsible for erosion are tidal and wave action and groundwater activity.

The motions of the sea which affect Chesapeake Bay are caused by the gravitational effects of the sun, the moon, and earth; and air movements or winds caused by differential heating of the earth. The moon, and to a lesser extent the sun, create ocean tides by gravitational forces. These forces of attraction, and the fact that the sun, moon, and earth are always in motion with relation to each other, cause the waters of the ocean basins to be set in motion. These tidal motions of water masses are a form of very long period wave which is apparent at any given point in the rise and fall of the water surface. In Chesapeake Bay tides are semidiurnal with a period of 12 hours and 25 minutes. The mean tidal fluctuation in the Bay is small, generally between one and two feet.

As water levels rise and fall, tidal currents are created. The largest tidal currents usually occur at inlets to lagoons and bays or at entrances to harbors. At such constricted places tidal currents generally flow in when the tide is rising (flood tide) and flow out as the tide falls (ebb tide). These tidal currents are a contributing factor to the erosion of the shoreline. In addition to creating currents which cause some erosion, the tides constantly change the level at which waves attack the beach.

Most of the waves observed on the ocean and the Bay are caused by winds blowing over the water and are called wind waves. These vary in size from mere ripples to large ocean waves as high as 100 feet. Wind waves are the cause of most of the shoreline erosion in the Bay Region. The height, length, and period (the time between successive crests) are determined by the fetch (the distance the wind blows over the water in generating the waves), the wind speed, the length of time the wind blows, and the decay distance (the distance the wave travels after leaving the generating area). Generally, the longer the fetch the stronger the wind and the longer the wind blows, the larger the waves will be. The water depth, if shallow, will also affect the size of the wave.

The amount of wave energy which reaches the shoreline is dependent on the nearshore gradient. A shallow nearshore will dissipate more wave energy than a deep nearshore. Also, less wave energy is received by a shoreline if there is a shoal, tidal flat, or aquatic vegetation immediately offshore. Similarly, a wide beach is better than a narrow beach because it is capable of dissipating wave energy for a longer period of time. Conversely, where the shoreline has none of the above natural features and wave action is strong, undercutting of the ground landward of the beach will cause sliding, slumping, and resultant loss of fastland.

Wave action is also one of the factors responsible for littoral transport which is defined as the movement of sediments in the nearshore zone by waves and currents. Littoral transport is divided into two classes: transport parallel to the shore (longshore transport) and transport perpendicular to the shore (onshore-offshore transport). Littoral transport is distinguished from the material moved, which is called littoral drift.

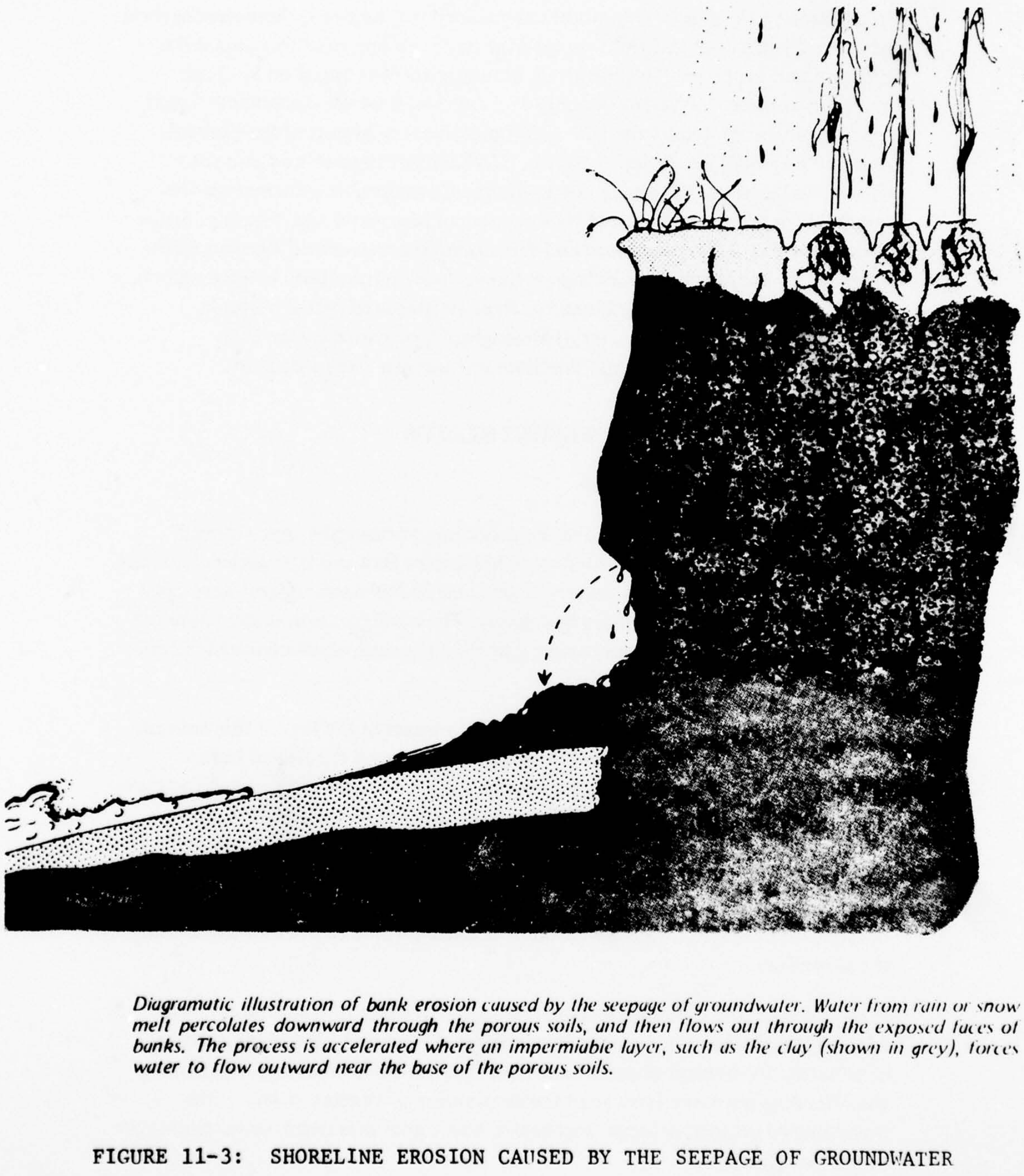
Onshore-offshore transport is determined primarily by wave steepness, sediment size, and beach slope. In general, high steep waves move material offshore and the low waves of long periods move material on shore. Longshore transport results from the stirring up of sediment by the breaking wave, and the movement of this sediment by the component of the wave in an alongshore direction, and by the longshore current generated by the breaking wave. While, due to the variability of wave approach, the direction of longshore transport may vary from day to day, and season to season, the net yearly transport is usually in one direction. In Chesapeake Bay, the longshore transport is generally toward the south.

Waves associated with hurricanes or other large storms can also be extremely damaging. These storms can generate very large, steep wind waves which can remove considerable material from the shore zone and carry it offshore. The strong winds of these storms often raise water levels and expose to wave attack lands of higher elevation that are not ordinarily vulnerable.

Another process which contributes to the erosion of the shoreline is the percolation or seepage of groundwater through the fastland and into the exposed shore zone.[1] As shown on Figure 11-3, taken from the Chester River Study prepared by the State of Maryland and Westinghouse Electric Corporation, water percolates downward through porous soils and flows out through exposed bank faces often causing sluffing at the toe of the bank.

To a much lesser degree the long term rise of sea level has also resulted in the inundation or loss of land to the Bay. In the lower Chesapeake Bay, an average rise of 0.01 feet per year has been recorded.[2] Also, at Fort McHenry in Baltimore, Maryland, the National Ocean Survey tide gage indicated a 0.6 foot rise in mean sea level between 1902 and 1962. These seemingly insignificant rates of increase can over the years inundate significant land area particularly where shorelands have very gentle slopes.

Lastly, rainfall and the resultant runoff can cause or contribute significantly to shoreline erosion, particularly in areas where the adjacent shoreline is rolling and broken and soils are made up of easily erodible materials. The runoff can also cause denuding of the vegetation on slopes causing them to be less resistant to the erosive forces of wave and tidal action.



Diagramatic illustration of bank erosion caused by the seepage of groundwater. Water from rain or snow melt percolates downward through the porous soils, and then flows out through the exposed faces of banks. The process is accelerated where an impermiable layer, such as the clay (shown in grey), forces water to flow outward near the base of the porous soils.

FIGURE 11-3: SHORELINE EROSION CAUSED BY THE SEEPAGE OF GROUNDWATER

DESCRIPTIVE PUBLICATIONS

In addition to the supporting studies mentioned in Chapter I, there were several additional sources of information used in the development of this appendix. Existing and proposed land use along the shoreline was based on land use mapping found in the various county and regional land use documents. Land use mapping prepared by the U.S. Geological Survey as part of the Central Atlantic Regional Ecological Test Site (CARETS) Program was also used where local land use data were not available. Considerable information was obtained from reports prepared by the states of Maryland and Virginia. *Shore Erosion in Tidewater Maryland* and *Historical Shorelines and Erosion Rates* prepared by the Maryland Geological Survey were particularly helpful reports as were a series of *Shoreline Situation Reports* prepared by the Virginia Institute of Marine Science. Aerial photography provided by the U.S. Department of Agriculture and the State of Maryland was also used.

PRESENT STATUS

Existing Problems and Conflicts

The natural processes discussed in the preceding paragraphs have claimed thousands of acres of land around the Chesapeake Bay and tributaries. Over the last 100 years alone, approximately 25,000 and 20,000 acres of land have been lost in Maryland and Virginia, respectively. The configuration of the shoreline has changed markedly in some areas, and islands, some of which exceeded 400 acres in size, have ceased to exist.

As can well be surmised, the most significant impact of the loss of this amount of land has been on the landowners who have witnessed the loss of both valuable shoreland and improvements that may have been constructed too close to the shoreline. Attempts to try to arrest the rate of erosion through either poorly designed or constructed protective measures have further frustrated property owners when their efforts proved futile. In some cases, landowners have given up the fight to the Bay waters and moved; however, there are many others who because of their livlihood or desire continue to live and work along the shoreline.

It should be noted that man has not been a passive factor in shoreline erosion. Man's activities have in many cases accelerated erosion by breaking down or eliminating the natural protective devices that inhibited erosion. Chief among the offending activities have been the elimination of vegetative cover, the breaching of protective berms and dunes, and sometimes detrimental alterations of the shoreline.

Unfortunately, there are many cases of either ill-advised or ill-judged development in areas that are subject to severe erosion. In cases such as this, man should have avoided the problem and encouraged wiser use of those areas subject to erosion or flooding.

Sediment, the product of erosion, has significant impacts on both the natural environment and man's use of the resource. Sediment from shoreline erosion may eventually be deposited in either natural or man-made navigation channels thus eventually requiring maintenance dredging and the problems normally associated with the disposal of the dredged material. An associated conflict between navigation and shoreline erosion is the matter of the erosion caused by the wakes from both commercial and recreational craft. This problem is most serious in areas adjacent to the major ship channels and is discussed in more detail in Appendix IX which addresses Navigation.

The sediment from erosion also has a considerable impact on water quality and the biota of the Bay. The sediment can cover productive oyster beds and valuable aquatic plants. The reduced light penetration into turbid waters can also be very detrimental to aquatic life.

An additional conflict related to shoreline erosion is the environmental impact of the various structural measures employed to prevent shoreline erosion. Many times erosion control structures are constructed in the intertidal zone and the adjacent shallow water areas. In such cases the structure and associated land fill often results in the loss of wetland habitat for many species of estuarine fish and wildlife. Structural measures can also alter currents and affect the flushing action in the vicinity of the structure. Lastly, in certain instances, the break up of the structure itself can result in unsightly debris that can be a navigational hazard.

Existing Critical Erosion Areas

In order to define those areas or reaches of tidal shoreline along the Bay and tributaries that are suffering critical losses of land, an inventory of historical erosion rates and the adacent land use was compiled. The erosion rates used in this compilation were developed by the Maryland Geological Survey and the Virginia Institute of Marine Sciences for the Maryland and Virginia portions of the Bay, respectively.

For the Maryland portion of the Bay, the Maryland Geological Survey, (MdGS), compared U.S. Coast and Geodetic Survey charts dating back as far as 1841 with the latest available charts to develop the linear recession and hence the shoreline erosion rates. The original work in this regard was done by T. H. Slaughter and presented in *Shore Erosion in Tidewater Maryland* (1949). More recently, as part of Maryland's Coastal Zone Management Program, the MdGS has updated and supplemented the earlier work with more recent map

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comparisons and field measurements from over 200 sites in tidewater Maryland. The results of this work are published in a series of reports titled *Historical Shorelines and Erosion Rates* (1975).

In Virginia, the Virginia Institute of Marine Science, using an approach similar to that explained above, has also developed erosion rates on a county basis for all tidewater counties in Virginia. The results of the Virginia studies are being published in county shoreline situation reports sponsored jointly by the National Science Foundation under its Research Applied to National Needs Program, and the Commonwealth of Virginia under the Coastal Zone Management Program.

In the delineation of the shoreline erosion rates the shoreline was broken down into workable lengths called reaches, which range from several hundred to several thousand feet in length. These reaches were established based on physiographic characteristics to include the change in erosion or deposition rate. The inventory of the erosion rates on a reach by reach basis for each tidal county in Maryland and Virginia is included in Tables A-1 and A-2, respectively, of Attachment A.

Present land use adjacent to the shoreline was obtained from comprehensive land use plans prepared by municipal, county, and regional planning agencies. In areas where land use maps were not available aerial photography provided by the U.S. Department of Agriculture and the State of Maryland, and land use mapping prepared by the U.S. Geological Survey as part of the Central Atlantic Regional Ecological Test Site (CARETS) Program were used. These sources are discussed in further detail in Appendix 4, Water-Related Land Resources.

Using the aforementioned erosion rate and land use information, areas were designated as critical if they met or exceeded the following criteria:

1. The erosion rate was equal to or greater than 3 feet per year regardless of adjacent land use.
2. The erosion rate was equal to or greater than 2 feet per year and the adjacent land use was intensive, i.e., residential, commercial, or industrial.

The above criteria were developed through meetings of the Advisory Group and the Flood Control, Navigation, Erosion and Fisheries Task Group; and the actual determinations of the critical reaches were made by the Corps of Engineers.

It should be noted that in those reaches where the erosion rate fell between 1.5 but less than 2.0 feet per year, the rate was "rounded" upward to 2.0 feet per year. This conservative approach was taken to compensate for the fact that the average rate for a reach probably dampened more severe rates at specific sites within the reach. It should also be noted that the reaches shown on Tables A-1 and A-2 were subdivided if the erosion

rate and land use factors were found to be critical in only a portion of the reach.

Using the above criteria and assumptions, the reaches listed on Table 11-1 were found to be critical. Table 11-1 lists each critical reach by county and state and includes a map reference number which may be used to locate the reach on Plates 11-1 through 11-3 which are located in the back of the appendix. Also included in Table 11-1 are the land use in the reach, reach length, erosion rate and an evaluation of existing structural shoreline protection measures within the reach.

For those reaches determined to be critical, a field investigation was conducted to inventory and evaluate the effectiveness of any existing shore protection measures. The evaluation included on Table 11-1 was based on the judgment of the individual making the inspection and did not include detailed engineering studies. A rating of "good" was assigned if the protection measure appeared to be properly designed and constructed, was continuous throughout the subreach, and was properly maintained and in good condition. A "fair" rating was given if the protection met all of the above criteria but was not continuous. In many cases around the Bay protection measures which are not continuous or properly tied into the fastland will be flanked and eventually eroded from the land side. Lastly, a "poor" rating was given if the protection was poorly maintained or constructed in addition to not being continuous.

Management Responsibilities

There are several Federal and State programs which provide varying degrees of assistance regarding shoreline erosion problems. The services range from technical advice to funding the design and construction of structural protection measures. The following paragraphs list those Federal and State agencies which have shoreline erosion programs and/or management responsibilities.

State of Maryland

Within the State of Maryland the Department of Natural Resources is the state agency which is most directly concerned with shoreline erosion. The Department is responsible for: (1) the development and implementation of a program to educate the public regarding shoreline erosion; (2) providing technical assistance to individual property owners and local governments having erosion problems and (3) administration of a fund to provide loans for construction of erosion control measures. As discussed earlier, both the work being accomplished by the Maryland Geological Survey on historical erosion rates and the development of Maryland's Coastal Zone Management Plan by the Energy and Coastal Zone Administration fall

TABLE 11-1
EXISTING CRITICALLY ERODING REACHES (MARYLAND)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ANNE ARUNDEL COUNTY						
	Chesapeake Bay						
1	Bodkin Pt. to Magothy Narrows	Residential	0.6	1.6*	Seawall		Poor
2	Magothy Narrows to Mountain Pt.	Residential	1.1	1.6*	Combination groin & stone bulkhead	1.1	Good
3	Back Creek to Fishing Creek	Residential	3.3	1.6*	Riprap timber bulkhead	2.1	Fair
4	Turkey Pt. to Dutchman Pt.	Residential	2.4	1.6*	Timber bulk-head & stone groin	0.4	Poor
					Timber bulk-head	1.4	
					Groin system	0.2	

*Rounded to 2 feet/year

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ANNE ARUNDEL COUNTY (Cont'd)						
5	a) Curtis Pt. to Cape Anne	Residential	2.6	3.3	Stone Revetment	0.5	Fair
	b) Battees Pt.	Open	3.5		Riprap	0.3	
					Timber bulkhead	1.3	
6	Persimmon Pt. to Hackett Pt.	Residential	2.8	2.5	Timber bulkhead	2.1	Fair
		Industrial	0.2		Concrete bulkhead faced with stone riprap		
7	Broadwater Creek to Cedar Pt.	Residential	1.3	2.5	Cinder block bulkhead	0.3	Fair
					Timber bulkhead	0.9	
8	Rockhold Creek to Calvert County Line	Residential	3.7	3.3	Timber bulkhead	0.2	Fair
		Open	1.5		Riprap groin system	0.8	

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ANNE ARUNDEL COUNTY (Cont'd)						
8	Rockhold Creek to Calvert County Line (Cont'd)				Timber bulkhead faced with riprap; stabilized by plank groin system	0.9	
	Patapsco River						
14	Hawkins Pt. to Bodkin Pt.	Open	5.3	3.0	Concrete bulkbulkhead	0.7	Fair
		Residential	2.4		Timber bulkhead	0.9	
		Industrial	0.6		Riprap	0.6	
	BALTIMORE COUNTY						
9	Miller Island	Open	N/A	3.8	None		
	CALVERT COUNTY						
	Chesapeake Bay						
11	From 2,300' N. of Plum Pt. to Parker Cr.	Residential	2.7	2.1	Wooden bulkhead	0.1	Fair

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	CALVERT COUNTY (Cont'd)						
12	From 2,300' S. of Flags Ponds to Cove Pt.	Residential	0.6	2.5	None		
	CECIL COUNTY						
	Northeast River						
15	Charlestown	Residential	1.2	1.6	Stone bulkhead	0.2	Poor
		Recreational	0.2				
16	Carpenter Pt.	Residential	0.4	1.6*	None		
17	Northeast Hgts.	Residential	1.6	1.6*	None		
18	Red Pt.	Residential	0.6	1.6*	None		
19	Turkey Pt.	Open	0.4	3.0	None		
	CHARLES COUNTY						
	Potomac River						
95	Riverside to Windmill Pt.	Commercial	1.8	3.0	None		
		Open	6.4				

*Rounded to 2 feet/year

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	DORCHESTER COUNTY						
	Chesapeake Bay						
20	Todds Pt. to Covey Creek	Residential	3.1	4.1	None		
		Open	9.3				
21	Mills Pt. to Ragged Pt.	Agricultural	6.8	5.4	Concrete rip-rap	5.3	Poor
22	Oyster Cove to the Big Broads	Residential	2.0	12.4	Jetty System	0.5	Poor
		Recreational	0.6		Groin System	0.6	
		Open	5.5		Junked cars & remains of bulkhead	0.8	
23	James Island	Open	6.8	8.1	None		
24	Barren Island	Open	7.7	5.4	None		
	Little Choptank River						
92	Oyster Cove to Hooper Pt.	Open	8.6	6.0	None		
	Nanticoke River						
93	Newfoundland Pt. to Clay Island	Open	11.2	3.0	None		
	HARFORD COUNTY						
	Bush River						
25	Bush Pt. to Chilbury Pt.	Military	5.7	5.0	None		

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	KENT COUNTY						
	Chesapeake Bay						
26	Betterton to Still Pond Creek	Open	5.9	3.0	None		
91	Tavern Creek to Huntingfield Creek	Residential	1.0	2.0	None		
	QUEEN ANNES COUNTY						
	Chesapeake Bay						
27	Love Pt. to Broad Creek	Residential	2.0	3.5	Wooden bulkhead	1.5	Poor
		Agricultural	1.5				
28	Broad Creek to 3/4 mi. S. of Carney Creek	Residential	2.6	1.6*	Wooden bulkhead	3.0	Fair
29	From 3/4 mi. S. of Carney Creek to Kent Pt.	Residential	2.8	3.3	Wooden bulkhead	2.8	Fair
		Agricultural	2.5				
		Open	2.5				
	Chester River						
30	Love Pt. to Piney Creek	Residential	1.4	1.5*	Wooden bulkhead	0.4	Fair
					Stone groin system	0.6	

*Rounded to 2 feet/year

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	QUEEN ANNES COUNTY (Cont'd)						
	Eastern Bay						
31	Kent Pt. to 4,500' North of Romancoke East shore	Residential Open	1.4 5.0	1.6	Wooden bulkhead	0.5	Fair
96	Shipping Creek	Open	1.3	4.0	None		
32	Bodkin Island	Open	1.0	3.9	None		
	SOMERSET COUNTY						
	Tangier Sound						
33	W. shore entrance of Upper Ihovafare to Vigoon Creek	Industrial Commercial Residential	1.8 1.8 2.5	1.8*	None		
94	Flatcap Pt. to Island Pt.	Open	7.2	4.0	None		

*Rounded to 2 feet/year

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ST. MARYS COUNTY						
	Chesapeake Bay						
36	From 4 3/4 mi. NW of Pt. No Pt. to St. Jerome Pt.	Residential	3.4	3.8	None		
		Open	3.2				
37	Deep Pt. to Point Lookout	Residential	2.0	6.0	Groin system-using 36" I.D. concrete cylinders	0.3	Fair
		Military	0.7		Newly constructed wooden groin field	0.1	
		Open	0.7		Junked cars	0.5	

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ST. MARYS COUNTY (Cont'd)						
37	Deep Pt. to Pt. Lookout (Cont'd)				Wooden bulkhead	0.3	
					Bulkhead faced with riprap	0.4	
					Corrugated steel sheathing bulkhead in addition to coffer jetties to stabilize adjacent riprap	0.8	
					Riprap	0.3	
	Potomac River						
39	White Neck Creek to Flood Creek	Residential	7.1	1.6*	Riprap	0.8	Fair

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ST. MARYS COUNTY (Cont'd)						
40	Smith Creek to Biscoe Creek	Residential	2.8	3.5	None		
41	St. Margerts Island	Open	0.7	4.1	None		
	TALBOT COUNTY						
	Chesapeake Bay						
42	700' E. of Wades Pt. to Harbor Cove	Open	4.3	73.0	None		
43	Harbor Cove to Knapps Narrows	Residential	1.0	2.1	None		
	Eastern Bay						
44	Wades Pt. to Tilghman Pt.	Residential	1.6	1.6*	Bulkhead	1.5	Poor
	Choptank River						
45	Lucy Pt. to Benoni Pt.	Open	2.3	3.0	None		
46	Tilghman Island	Residential	6.0	3.6	Concrete Revetment	0.7	Fair
		Open	6.9		Wooden bulkhead	0.7	
					Riprap	0.6	

*Rounded to 2 feet/year

TABLE 11-1 (MARYLAND) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	TALBOT COUNTY (Cont'd)						
47	Poplar Island	Open	N/A	7.2	None		
48	Sharps Island	Open	N/A	62.8	None		
	WICOMICO COUNTY						
	Nanticoke River						
49	Stump Pt. to Bivalve	Residential	2.1	1.9*	Combination wooden bulkhead stone jetty	0.5	Poor
					Timber bulkhead	0.6	
					Wooden groin	0.7	

TABLE 11-1
EXISTING CRITICALLY ERODING REACHES
(VIRGINIA)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ACCOMACK COUNTY						
50	Tangier Island Large	Residential	0.5	20.0	Bulkhead jetty	0.6	Poor
		Wetland	2.2				
		Open	0.1				
51	Little Fox Island	Wetland	0.5	27.4	None		
52	Shanks Island	Wetland	1.6	13.2	None		
53	Big Ledge Island	Wetland	0.1	4.6	None		
54	Pig Pt. to West Mouth Back Creek	Wetland	6.6	4.1	Riprap Bulkhead 11 groins	0.02 0.4	Fair
55	West Marsh Tump Island N. of Beach Island	Wetland	0.7	85.4	None		
56	Sound Beach to Ware Pt.	Wetland	2.3	5.0	None		
57	Bluff Pt. – Butcher Creek Pt.	Wetland	4.0	3.2	Riprap	0.05	Poor
58	Milby's Pt. – Sandy Pt.	Wetland	2.0	3.4	None		
59	Chaddock Creek – Poles Bluff	Forest	1.9	4.9	None		

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ESSEX COUNTY						
	Rappahannock River						
60	Blandfield Pt. to Lewis Creek	Wetlands	0.9	4.4	None		
61	Jenkins Landing to Piscataway Creek	Residential	0.8	2.3	Concrete bulkhead	0.2	Fair
					Timber bulkheads & wooden groins	0.3	
62	1/2 mi. S. of Eubank to Essex County Line	Residential	0.5	3.1	Timber bulkhead	0.2	Poor
		Wetlands	0.5				
		Open	4.2				
		Agriculture	0.7				
	CITY OF HAMPTON						
	Chesapeake Bay						
63	Northend Pt. to Old Pt. Comfort	Residential	4.3	4.5	Bulkhead	2.3	Fair
		Wetlands	4.2		Groin	1.1	
	James River						
64	Old Pt. Comfort to City Limits	Residential	3.2	2.1	Bulkhead	2.7	Fair
					Groin	0.1	

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	ISLE OF WIGHT COUNTY						
	James River						
65	Day Pt. to Williams Creek	Wetlands	3.5	3.4	None		
		Open	2.3				
		Agriculture	1.9				
	LANCASTER COUNTY						
	Chesapeake Bay						
66	Indian Creek to Tabbs Creek	Open	0.4	6.4	None		
		Agriculture	1.0				
67	Tabbs Creek to Windwill Pt.	Wetlands	1.1	7.5	None		
		Open	3.5				
		Agriculture	0.3				
	MATTHEWS COUNTY						
	Piankatank River						
68	Cherry Pt. to Queens Creek	Residential	3.0	1.7*	Riprap	0.6	Fair
					Bulkhead	1.3	
					Groin	1.1	

*Rounded to 2 feet/year

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	MAT HEWS COUNTY (Cont'd)						
	Chesapeake Bay						
69	Cheery Pt. to Gwynn Island	Open Agriculture	3.7 0.5	5.8	Bulkhead Groin	0.4 3.0	Fair
70	Rigby Island to Winter Harbor Cove	Barren Open	2.2 0.3	4.6	1 - jetty		Fair
	MIDDLESEX COUNTY						
	Rappahannock River						
71	Essex County Line to Mud Creek	Open	0.9	6.5	None		
72	Parrots Creek to Smoky Pt.	Residential	0.5	2.2	None		
73	Lagrange Creek to Urbana Creek	Residential	1.0	2.7	Timber bulkheads & short wooden groins	0.9	Poor

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	MIDDLESEX COUNTY (Cont'd)						
74	Woods Creek to Stingray Pt.	Residential	1.1	4.1	Wooden groins	0.3	Poor
		Open	2.6		Riprap	0.3	
		Agriculture	1.6		Timber bulkhead & wooden groin	0.1	
					Riprap revetments & wooden groin	0.1	
					Timber bulkhead	0.1	
	NORTHHAMPTON COUNTY						
75a	Sparrow Pt. – S. Area	Forest	0.7	4.0	None		
	Creek S. of Sparrow Pt. – Nassawadox Pt.	Forest	4.0	5.1	Riprap	0.3	Fair

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	NORTHHAMPTON COUNTY (Cont'd)						
75b	Honeymoon Isle spit	Agricultural	0.7	3.0	None	0.1	Fair
		Agricultural & Forest	3.2	5.1	Riprap 32 groins		
76	Westcut Pt.	Forest	1.1	3.2	None		
	Scape Charles Harbor - 3/4 mi. S.	Agricultural & Forest	0.7	7.6	1 jetty		
	NORTHUMBERLAND COUNTY						
	Potomac River						
77	Cornish Creek to Thickett Pt.	Residential	0.2	2.8	Timber bulkhead & wooden groins	1.0	Fair
78	Travis Pt. to Kingscote Creek	Open	0.6	3.0	Groins	0.3	Poor
		Agricultural	0.1		Bulkheads	0.3	
					Revetments	0.4	
79	Honest Pt. to Ginny Beach	Open	8.0	4.8	None		
		Agricultural	5.3				

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	NORTHUMBERLAND COUNTY (Cont'd)						
	Chesapeake Bay						
80	Taskmers Creek to Warehouse Creek	Residential	0.5	2.6	Riprap revetment & groin	0.1	Fair
					Riprap	0.1	
81	Jarvis Creek to Bluff Pt.	Open Agricultural	2.0 0.4	5.2	None		
	RICHMOND COUNTY						
	Rappahannock River						
82	Pearson Island (Lancaster Creek)	Agricultural	0.3	3.7	None		

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Critical Subreaches: Type	Length of Protection (mi.)	Overall Effectiveness of Protection
	VIRGINIA BEACH CITY OF						
	Southern Chesapeake Bay						
84	1 mi. East of City Limits to Lynnhaven Inlet	Residential	3.9	4.4	Groin		Poor
85	Fort Story to Cape Henry	Residential	2.1	4.5	Stone revetments	0.7	Fair
	WESTMORELAND COUNTY						
	Potomac River						
86	Church Pt. to Horsehead Cliffs	Residential	1.1	3.5	Timber bulkhead	0.5	Poor
		Open	0.5		Timber bulkhead & wooden groins	6.5	
		Agricultural	3.5		Groins	0.1	
87	Glebe Creek to Ragged Pt.	Residential	0.6	3.6	Timber bulkhead & wooden groins	0.3	Poor
		Open	1.1		Timber bulkhead	0.7	
		Agricultural	1.1				

TABLE 11-1 (VIRGINIA) (Continued)

Map Ref	Reach Location	Critical Subreach Land Use	Critical Subreach Length (mi.)	Erosion Rate Ft./Yr.	Shoreline Protection Along Cirtical Subreaches		
					Type	Length of Protection (mi.)	Overali Effectiveness of Protection
	YORK COUNTY						
	York River						
88	Skimino Creek to Bigler Mill Pt.	Residential	0.3	2.4	None		
89	Wormley Creek to Sandbox	Residential	0.7	3.5	Riprap	1.7	Fair
		Industrial	1.6		Bulkhead	1.5	
		Open	0.4				
	Chesapeake Bay						
90	Sandbox to York Pt.	Residential	0.4	2.8	Riprap	0.1	Fair
					Bulkhead	1.1	

under the jurisdiction of the Department of Natural Resources. The Department also has the responsibility for granting permits for construction of shoreline erosion control structures.

Commonwealth of Virginia

Within the Commonwealth of Virginia,the Marine Resources Commission, the Soil and Water Conservation Commission, Office of the Secretary of Commerce and Resources, and the Virginia Institute of Marine Science have the primary responsibilities regarding matters pertaining to the coastal zone and shoreline erosion. However, where local wetlands boards exist, they have the initial responsibility for granting permits for erosion control projects on wetlands. The Soil and Water Conservation Commission is responsible for the coordination of the shore erosion control programs of all state agencies and institutions and secures the cooperation and assistance of related Federal agencies. The Office of the Secretary of Commerce and Resources is the Commonwealth Agency responsible for the development of Virginia's coastal zone management program. The Virginia Institute of Marine Science serves as a technical advisor to the aforementioned commissions and conducts the full range of engineering and environmental studies in the coastal zone.

U.S. Army Corps of Engineers

The Congress has directed the Corps of Engineers to carry out programs established to protect and maintain the Nation's shorelines. The programs include: (1) research to determine the causes of beach erosion, (2) investigations and studies of specific beach erosion problems, and (3) construction of shore protection and beach restoration projects.

Before 1930, Federal interest in shore erosion problems was limited to the protection of Federal property and improvements for navigation. At that time, an advisory "Board of Sand Movement and Beach Erosion" appointed by the Chief of Engineers was the principal instrumentality of the Federal Government in this field. The need for a central agency to assemble data and provide engineering experience regarding coastal protection was recognized by Congress with creation of the Beach Erosion Board authorized by Section 2 of the River and Harbor Act approved 3 July 1930 (P.L. 520, 71st Congress, 33 U.S.C. 426). The Board was empowered to make studies of beach erosion problems at the request of, and in cooperation with cities, counties, or states. The Federal government bore up to half the cost of each study but did not bear any construction costs unless federally owned property was involved. An Act of Congress approved 13 August 1946 (P.L. 727, 79th Congress) established a policy of Federal aid in construction costs where projects protected publicly owned shores. An Act approved 28 July 1956 (P.L. 826, 84th Congress) amended

that basic beach erosion legislation to authorize Federal participation in the protection of private property if such protection was incidental to the protection of publicly owned shores, or if such protection would result in public benefits. The River and Harbor Act of 1962 (P.L. 87-874) increased the proportion of construction costs borne by the Federal government and made the total cost of studies a Federal responsibility. An act approved 7 November 1963 (P.L. 88-172) abolished the Beach Erosion Board, transferred its review functions to the Board of Engineers for Rivers and Harbors, and established the Coastal Engineering Research Center as a research and development element of the Corps. Lastly, Section 54 of the Water Resources Development Act of 1974 (P.L. 93-251) approved 7 March 1974, authorized a program to develop, demonstrate, and disseminate information about low cost means to prevent and control shoreline erosion. This Section also provided for the establishment of a Shoreline Erosion Advisory Panel. Section 55 of this same act authorized technical and engineering assistance to non-Federal public interests in developing structural and non-structural methods of preventing damages attributable to shore and streambank erosion.

Congress has authorized Federal participation in the cost of restoring and protecting the shores on the Atlantic and Pacific Oceans, the Gulf of Mexico, the Great Lakes, and lakes, estuaries, and bays directly connected therewith. The erosion must be caused by wind and/or tidal generated waves; therefore, the authorization does not cover erosion at upstream locations caused by streamflows. Federal participation is limited to restoration of the historic shoreline. Any extension of the shoreline or creation of new beach areas will be at the expense of non-Federal interests.

The extent of Federal participation toward beach erosion projects varies from 100 percent to none, dependent upon the shore ownership, use, and type and incidence of benefits. Table 11-2 summarizes the extent of Federal participation in beach erosion control projects for five categories of beach ownership.

Those projects which provided hurricane, tidal, and lake flood protection and were authorized in the 1958 Flood Control Act established a precedent of limiting the Federal share of project cost to a maximum of 70 percent. It has been Corps practice to include similar cost sharing for all subsequent justified hurricane protection projects recommended for Congressional authorization. When the normal local costs of land, easements, rights-of-way, and relocations amount to less than 30 percent of total first costs, the difference is required as a local cash contribution; when those local costs exceed 30 percent, they become the minimum requirement. Successful protection against hurricane and tidal flooding on the open coast frequently requires that the shoreline be concomitantly stabilized against erosion. For multiple-purpose hurricane protection and beach erosion control projects, Section 208 of the 1970 Flood Control Act provides

TABLE 11-2

LIMITS OF FEDERAL PARTICIPATION TOWARDS BEACH EROSION CONTROL PROJECTS

Shore Category	Maximum Level of Federal Aid: Construction	Maximum Level of Federal Aid: Maintenance
I Federally owned	100%	100%
II Publicly owned, non-Federal parks and conservation areas	70% (1) (2)	None
III Publicly owned, non-Federal other than parks and conservation areas	50%	None
IV Privately owned, protection will result in public benefits (3)	50% (1) (2) multiplied by the ratio of public benefits along Cat. IV shore to total benefits along Cat. IV shore	None
V Privately owned, protection will not result in public benefits susceptible of evaluation	None	None

(1) Cost-sharing percentages do not include lands, easements, and rights-of-way, which are entirely a non-Federal cost.

(2) Federal aid may be provided for beach nourishment. (Generally, a time limit of 10 years has been placed on Federal participation. However, the current trend is to recommend Federal participation for the life of the project.)

(3) Privately owned shores under public control, as through a sufficiently long-term lease assuring realization of public benefits throughout the economic life of the project, may be treated as Category III shores in determining Federal aid.

discretionary power to the Secretary of the Army acting through the Chief of Engineers to authorize a Federal share up to 70 percent of the project costs exclusive of land costs.

In order to determine if any Federal participation is warranted in a beach erosion control project, the Corps may undertake an investigation under specific authorization by Congress or resolutions by either the House or Senate Public Works Committees. Given the authority and the study funding, the Corps investigates the engineering and economic feasibility of various control measures and their associated environmental and socio-economic impacts and makes recommendations to Congress regarding solutions to the problem. If approved and authorized by the Congress, Federal funds in accordance with the limitations noted on Table 11-3 could be used for construction of a project.

The Corps may also undertake investigations under general continuing authorities. Section 103 of the River and Harbor Act of 1962 provides authority for the Corps to develop and construct small shore and beach restoration and protection projects that have not already been specifically authorized by Congress. A project is adopted for construction under Section 103 only after detailed investigation and study have evaluated the engineering feasibility, economic justification, and the environmental and socio-economic impact of the project. Each project is limited to a Federal cost of not more than $1,000,000.

U.S. Department of Agriculture, Soil Conservation Service (SCS)
The SCS was created by the Soil Conservation Act in 1935, originally for the purposes of developing and maintaining a national soil conservation program. In 1954, the Watershed Protection and Flood Prevention Act expanded its mission to preserving and protecting the Nation's land and water resources.

Under the 1954 Act, SCS is authorized to conduct small watershed investigations. Under the Food and Agriculture Act of 1962, the SCS is responsible for assisting local groups in multi-county areas to sponsor long-range resource planning and development. Under these statutes, the SCS provides:

1. Technical assistance to individual landowners for protecting,treating and using land, and shorefront property.
2. Technical and financial assistance for watershed protection and flood prevention for areas no larger than 250,000 acres (Small Watershed Program).
3. Planning, development and financial assistance in larger areas (Resource Conservation and Development Program). Recipients of assistance are public agencies and nonprofit organizations.

National Oceanic and Atmospheric Administration

The Federal responsibility for administering the Coastal Zone Management Act has been assigned to the Office of Costal Zone Management (OCZM) of the National Oceanic and Atmospheric Administration (NOAA) under the direction of the Secretary of Commerce. NOAA serves as the primary Federal-State coordinating entity and will administer the grant program which may finance up to two-thirds of the annual costs of State CZM program development and implementation. NOAA will monitor the administration of State CZM plans to insure that they are refined and updated as needed.

CHAPTER III

FUTURE SHORELINE EROSION PROBLEM AREAS

This chapter includes a discussion of those shoreline areas which are presently not classified as critical erosion areas, but that have the potential to become problem areas dependent on their future development. The approach used to define the future problem areas parallels that used to define the existing problems. By defining the emerging problem areas appropriate measures can be taken by both the public and private sectors to avoid these future problems.

ASSUMPTIONS AND METHODOLOGY

As noted above the method employed to delineate future problem areas is essentially the same as that used to define the existing critical areas. As before, the principal factors used in the analysis are shoreline erosion rate and the adjacent land use. For the future problem analysis it was assumed that the historical erosion rates presented in Tables A-1 and A-2 of Attachment A are reflective of future erosion rates in those same reaches. Based on the work by the Maryland Geological Survey referenced earlier in this appendix, this assumption appears to be reasonable as erosion rates in selected reaches did not appear to change significantly between 1949 and 1975.

Regarding land use, it was assumed that future land use adjacent to the shoreline would develop as shown in the latest regional, county or municipal land use planning documents. While the local land use plans reflected that the projected level of development would be reached in time frames varying from 15 to 25 years, it was assumed for this analysis that the plans reflected optimum development of the area. It should be noted that several counties in the Northern Neck Area of Virginia to include Essex, Middlesex, King and Queen, Mathews, and King William presently have no future land use plans. For this analysis it was assumed that the present land use in these predominantly rural counties would not change significantly in the planning period.

Given the historical erosion rates and the projected future land use adjacent to the shoreline, the entire shoreline was reviewed to determine if any future development was proposed in areas subjected to significant

shoreline erosion. As before, the criteria for delineation of a critical reach was that the erosion rate equal or exceed 2 feet per year in an area that was proposed for intensive land uses to include residential, commercial, or industrial.

FUTURE PROBLEM AREAS

Using the assumptions and methodology discussed above, the additional shoreline delineated as critical based on projected future land use is shown on Tables 11-3 and 11-4 for the states of Maryland and Virginia, respectively. In addition to an identification of the reach, a map reference number, the erosion rate and the critical reach length are also included on Tables 11-3 and 11-4. The map reference numbers are keyed to Plates 11-1 through 11-3, included at the end of this appendix. Based on the projected land use it has been determined that an additional 44.4 miles of Bay shoreline has the potential to become a serious problem. It should be clearly noted that this is in addition to the nearly 300 miles of shoreline that is classified as critical based on the present condition analysis outlined in Chapter II of this appendix.

SENSITIVITY ANALYSIS

The purpose of this segment of the report is to provide an assessment of how sensitive the delineation of future critical reaches is to the assumptions made in the adopted methodology. As indicated in the description of the methodology the two factors considered in the analysis were shoreline erosion rate and the shoreline land use.

Regarding shoreline erosion rate, the rate that was adopted as a criteria for defining a critical area was 2 feet per year. For this sensitivity analysis this criteria was revised and the amount of shoreline that would be classified as critical using rates of 1 foot per year and 3 feet per year was determined.

Assuming that the critical erosion rate was only 1 foot per year, the total length of critical shoreline was found to be approximately 80 miles or nearly double the 44.4 miles classified as critical using the 2 feet per year criteria. When the criteria was raised to 3 feet per year, it was noted that the length of critical shoreline was reduced to only approximately 20 miles. Based on the above, it is apparent that the length of shoreline that

TABLE 11-3
FUTURE CRITICALLY ERODING REACHES
(MARYLAND)

Map Ref	Locality Water Body Reach Designation	Erosion Rate (ft./yr.)	Critical Sub-Reach Length (mi.)
	ANNE ARUNDEL COUNTY		
	Chesapeake Bay		
1	Bodkin Point	1.6*	0.6
2	Persimmon Point	2.5	0.5
	CALVERT COUNTY		
	Chesapeake Bay		
3	From 2,300' N. of Plum Point to Parker Cr.	2.1	3.3
4	From 2,300' S. of Flags Ponds to Cove Point	2.5	1.0
5	Cape Anne	2.5	0.3
	CECIL COUNTY		
6	Charlestown to Carrerter Point	1.6*	1.9
7	Northeast Heights to Red Point	1.6*	3.0
	KENT COUNTY		
	Chesapeake Bay		
9	2 miles south of Tolchester Beach to Tavern Creek	2.7	3.0
	QUEEN ANNES COUNTY		
	Chesapeake Bay		
11	Broad Creek to ¾ mile south of Carney Creek	1.6*	1.4
12	Jackson Creek to Piney Cove	3.0	5.3
	Eastern Bay		
13	Greenwood to Bennett Point	3.0	3.0
	WICOMICO COUNTY		
	Nanticoke River		
14	Roaring Point	1.9*	1.0
15	Bivalve Harbor to 1 mi. north	1.9*	1.0

*Rounded to 2 feet/year

TABLE 11-4
FUTURE CRITICAL ERODING REACHES
(VIRGINIA)

Map Ref	Locality Water Body/ Reach Designation	Erosion Rate (ft./yr.)	Critical Sub-Reach Length (mi.)
	GLOUCESTER COUNTY		
	Ware River		
16	Ware River Point to Old House Creek	2.5	2.2
	Mobjack Bay		
17	Ware River Point to Turtle-neck Point	1.8*	2.0
	York River		
18	Sandy Point to east of Perrin River	1.7*	2.8
	CITY OF HAMPTON		
	Back River		
19	Harris Creek to North End Point	1.9*	2.5
	LANCASTER COUNTY		
	Rappahannock River		
20	Wyatt Creek to Greenvale Creek	2.6	0.1
21	Navy Auxiliary Air Force to Mulberry Creek	2.5	0.3
22	Mulberry Creek to Curletts Point	3.7	0.2
	Corrotoman River		
23	Eastern Shoreline	2.7	1.5
	NORTHUMBERLAND COUNTY		
	Potomac River		
24	Eastern Shoreline of Wilkens Creek	2.3	0.2
	Chesapeake Bay		
25	Taskmers Creek to Ware-house Creek	2.6	1.0
	RICHMOND COUNTY		
	Rappahannock River		
26	Morattico Creek to Tarpley Point	1.8*	0.4

*Rounded to 2 feet/year

TABLE 11-4 (Cont'd)

Map Ref	Locality Water Body/ Reach Designation	Erosion Rate (ft./yr.)	Critical Sub-Reach Length (mi.)
	RICHMOND COUNTY (cont'd)		
	Rappahannock River		
27	Tarpley Point to Sharps Road Point	1.8*	1.0
28	Sharps Road Point to Rechardson Creek	2.0	0.2
29	Waverly Point to McGuire Creek	2.6	1.6
	WESTMORELAND COUNTY		
30	Ragged Point to Jackson Creek	2.7	2.5
	YORK COUNTY		
	York River		
31	Skimino Creek to 1.8 mi. south	2.4	0.6

is classified as critical varies inversely as the erosion rate criteria, i.e., the higher (more severe) the criteria the lower the total length of critical shoreline.

As discussed above, future land use was the other factor used in the critical shoreline evaluation. The future land use adjacent to the shoreline was based entirely on the land use plans prepared by local and regional planning agencies. In the event the future shoreline land use as portrayed in the planning documents changes, it could directly affect the total length of shoreline classified as critical. For example, if a length of shoreline previously zoned as agricultural is reclassified as residential, it could qualify as critical if the erosion rate was significant. As another example, recent trends toward zoning for less intensive use of shorelands because of the threat of erosion or tidal flooding could result in significantly less shoreline qualifying as critical.

The results of the above sensitivity analysis indicate that dependent on the basic assumptions made, the length of shoreline that should be classified as critical can vary significantly. It is felt, however, that the basic assumptions regarding land use and erosion rate made for this report have resulted in a representative assessment of the shoreline erosion problem in Chesapeake Bay.

CHAPTER IV

MEANS TO SATISY NEEDS

This chapter includes a survey of the various structural and non-structural measures that can be employed to prevent or arrest shoreline erosion. The applicability of the measures in various locations is also discussed together with the common failures that can be encountered as the result of improper design or construction.

STRUCTURAL SOLUTIONS

Structural solutions are defined as those manmade structures that are designed to either prevent waves and tidal action from reaching erodible material or that retard the longshore transport of littoral drift and thus aid the build-up of the natural nearshore defenses. Bulkheads and revetments are the most commonly used structures that prevent erosive forces from reaching the fastland while groins and beach nourishment are most frequently employed in the Region to build up the nearshore. The following paragraphs include a discussion on the above mentioned structural measures and their general design characteristics.

It should be noted that the following information is provided only as a general description and not a detailed design. To develop a detailed design for a specific location requires the evaluation of many factors to include soil composition and foundation material, shoreline exposure and configuration, offshore slope, presence of littoral drift, and the cost and availability of construction materials. Failure to adequately consider the above factors can result in the loss of an expensive structure and the subsequent loss of the land being protected.

Bulkheads

A substantial shorefront beach area and a sloping nearshore bottom serve to dissipate wave energy and are the primary means of reducing wave damage caused by major storms. A vertical wall, sometimes known as a bulkhead, serves as a secondary line of defense from these storms. Bulkheads can be constructed of wood, stone, concrete, or metals, but are commonly made of wood, with a framework of pilings and cross-timbers called wales covered with a sheathing of thick boards nailed or bolted to the framework as shown on Figure 11-4. The main purpose of this

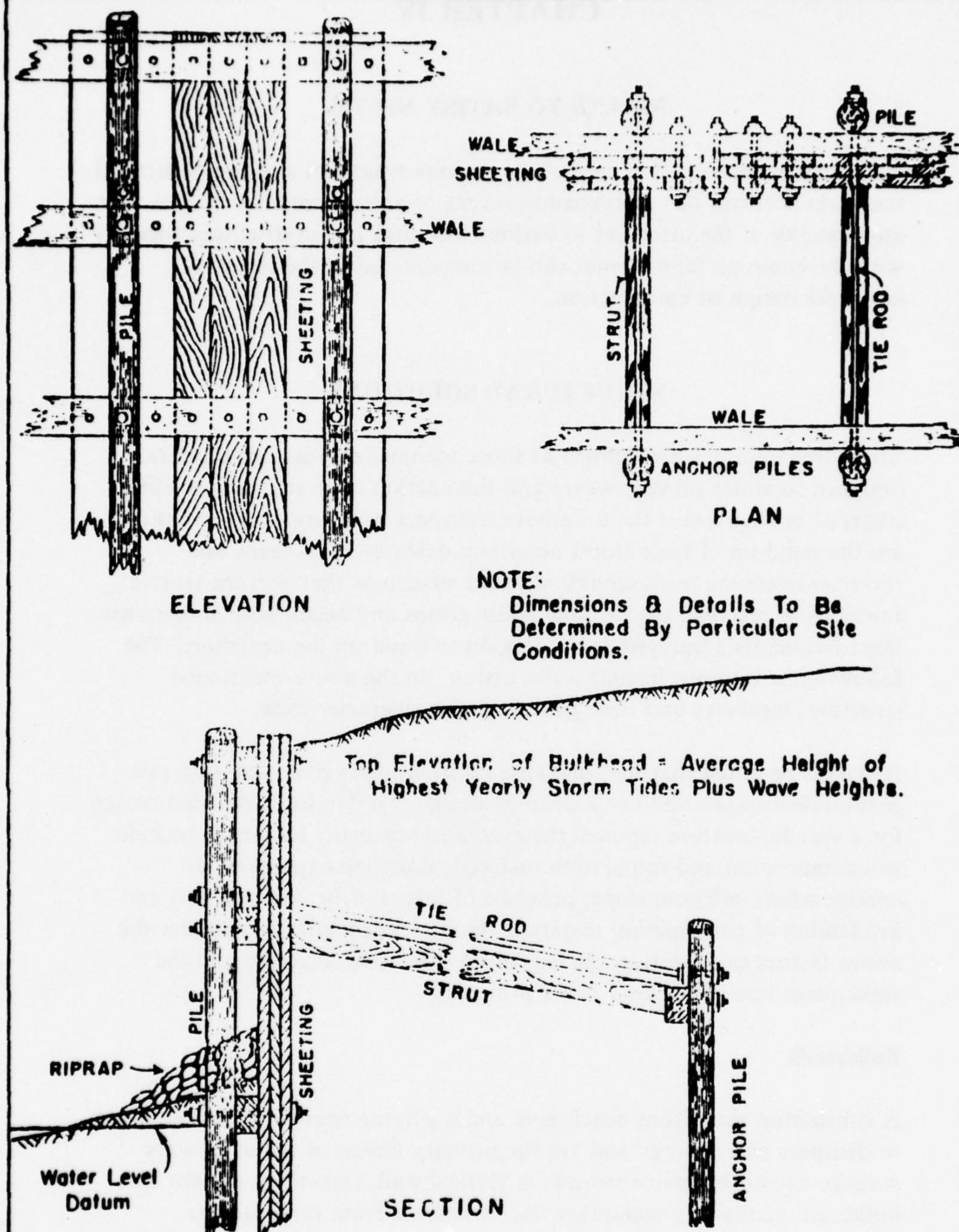


FIGURE 11-4

TIMBER SHEET PILE BULKHEAD

structure is to retain earth behind it, and to deflect the energy of incoming waves. Areas around Chesapeake Bay where such protection can be most effectively used are in sheltered waters such as coves, harbors, and in small bays. In open waters, such as on the Bay proper, bulkheads unless properly designed with riprapped toes may be relatively ineffective as the severity of the water action causes scouring at the bottom of the structure and eventually undermines the bulkhead itself.

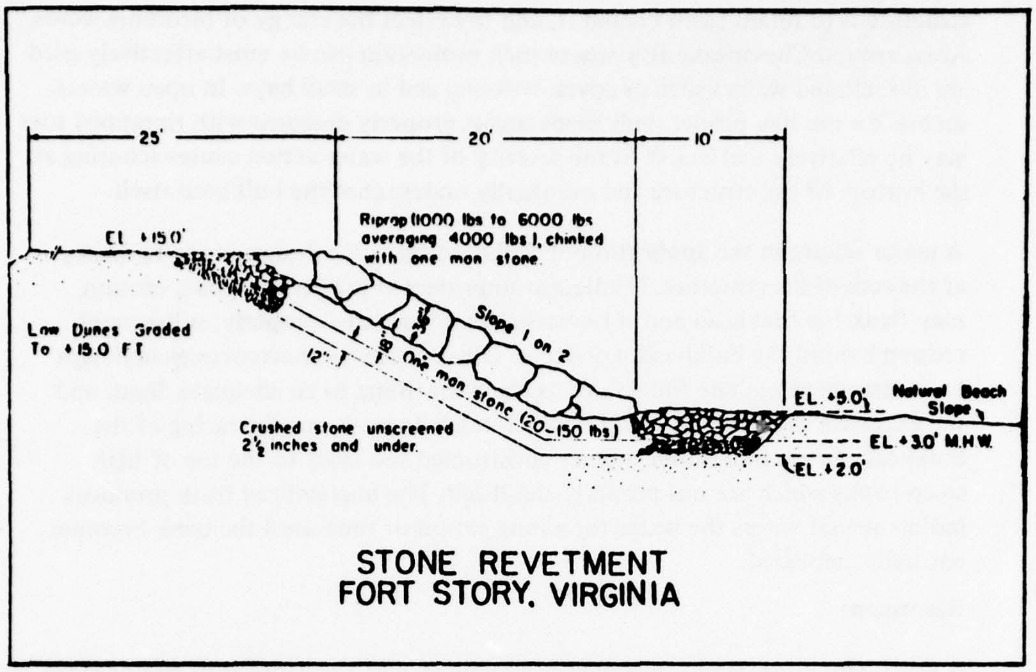
A major failure in the application of bulkheads is in the design of the tie-backs at the ends of the structure. If adjacent unprotected properties erode, erosion may flank the bulkhead and if tie-backs are not secured properly, subsequent erosion behind the bulkhead will occur. Other common shortcomings in design or construction include the failure to place sheathing to an adequate depth and the excessive surcharge of backfill which tends to push out the facing of the bulkhead. Often too, bulkheads are constructed too close to the toe of high steep banks which are not properly stabilized. The unstabilized bank produces sediment that enters the water for a long period of time until the bank becomes naturally stabilized.

Revetment

A revetment consists of armoring the sloping face of the shore with one or more layers of riprap or concrete (see Figure 11-5). The sloping characteristic in this design serves to dissipate wave energy as the water rolls up the incline. Riprap composed of stone, chunks of concrete, rubble or brick is the most common type of construction employed in the Bay area to form a slope barrier between fastland and water. The irregular surface also serves to break up water momentum and provide niches which capture sediment and thus add stability. Gabions consisting of riprap enclosed in wire mesh cages may also be used. These baskets capture sediment and grow protective vegetation which eventually blends the structure into the background.

Interlocking blocks have also been used to form revetments; however, in such a design, the toe of the structure is very susceptible to undermining and the design should incorporate a piling at the toe which is reinforced by heavy stone to insure against such a failure. The toe of the structure should extend at least two feet below mean low water unless it is in an area of low wave energy.

Riprap can be used to effectively retard erosion in the most severe cases. It has been used in combination with bulkheads where the adjacent shoreline exhibits high bluff formations. The bulkhead, if constructed far enough seaward to allow for suitable backfill sloping, can adequately retain the land while the riprap adjacent to the bulkhead can dissipate the destructive wave energy thus protecting the bulkhead. In certain ineffective attempts to halt erosion, unsuitable materials such as junked car bodies, engines, and tires have been used as riprap to absorb wave energy.



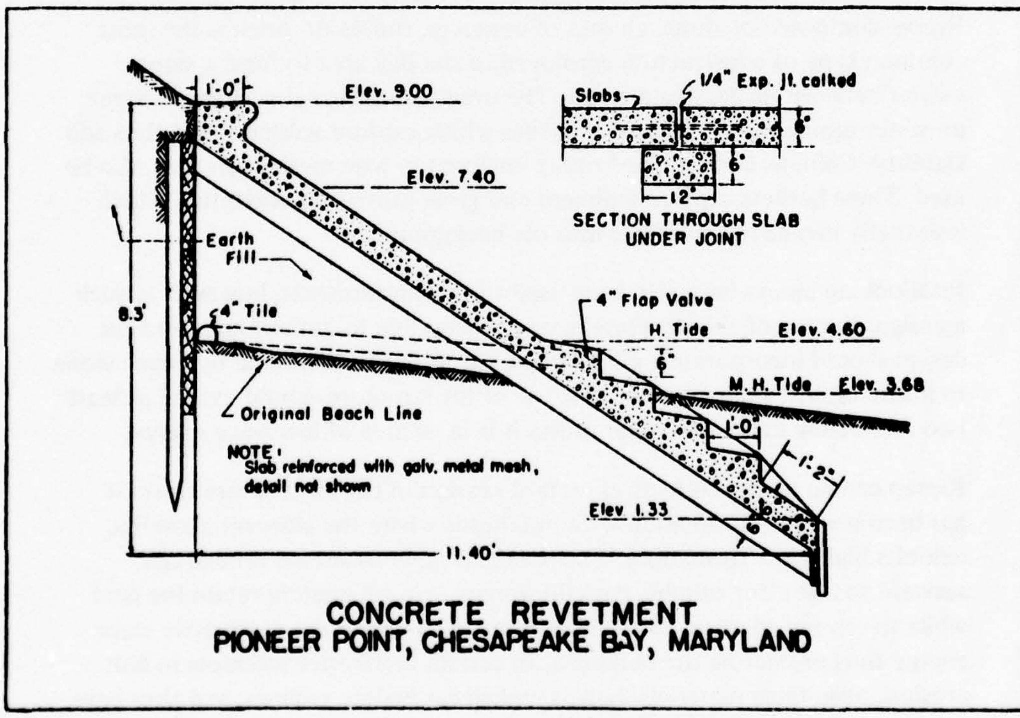


FIGURE 11-5: TYPICAL REVETMENTS

Groins

Long ago man noted that obstructions on a beach such as logs or wrecks would trap sand along the beach and cause the beach to widen. Such observations led to the development of the groin, a barrier-type structure which extends perpendicular to the shoreline from the backshore into the littoral zone of sand movement. (See Figure 11-6). The basic purpose of a groin is to interrupt alongshore sand movement in order to accumulate sand on the shore or to retard sand losses.

In earlier times, prior to extensive development of major portions of the shoreline, the natural supply of sand was plentiful and in many instances groins succeeded remarkably well. This success led to further excessive and sometimes indiscriminate use of groins. Many groin fields completely interrupted the flow of sand to downdrift areas and thus damaged adjacent sections of the shore.

In order to minimize damage to the shoreline downstream from a groin it has to be designed with the top profile not higher than that of a beach of reasonable dimensions. When full, a groin of this type will permit the stream of sand to pass over its top and continue on downstream to nourish the neighboring shores. Since more beaches are being protected and less sand is available to the stream to fill groins naturally, it is frequently necessary to place sand artificially to fill the area between the groins. Groins should not be built unless properly designed for the particular site and the effects of the groins on adjacent beaches have been adequately studied by an engineer experienced in this field.

Each groin should consist of three sections: a shoreward horizontal section, a slope section, and an outer horizontal section. The shoreward horizontal section should be at the ultimate elevation desired for the beach. The length of this section is determined by the width of upper beach desired, but it normally would extend from the width of the beach to about the mean high water line. The slope section should approximately parallel the slope of the foreshore that the groin is expected to maintain. The outer section is most often horizontal at as low an elevation as is consistent with economy of construction and safety, and still be higher than the design updrift bottom slope. The initial suggested spacing for groins should be two to three times the length, measured from the high water line.

A difficulty often encountered in the use of groins occurs when groins are used to build a beach adjacent to a bluff. Flanking on the bluff end of the structure may result because the groin tends to guide incoming waves along itself and into the bluff. The characteristic behavior is for the groins to be flanked, one by one, from the downdrift direction until the entire

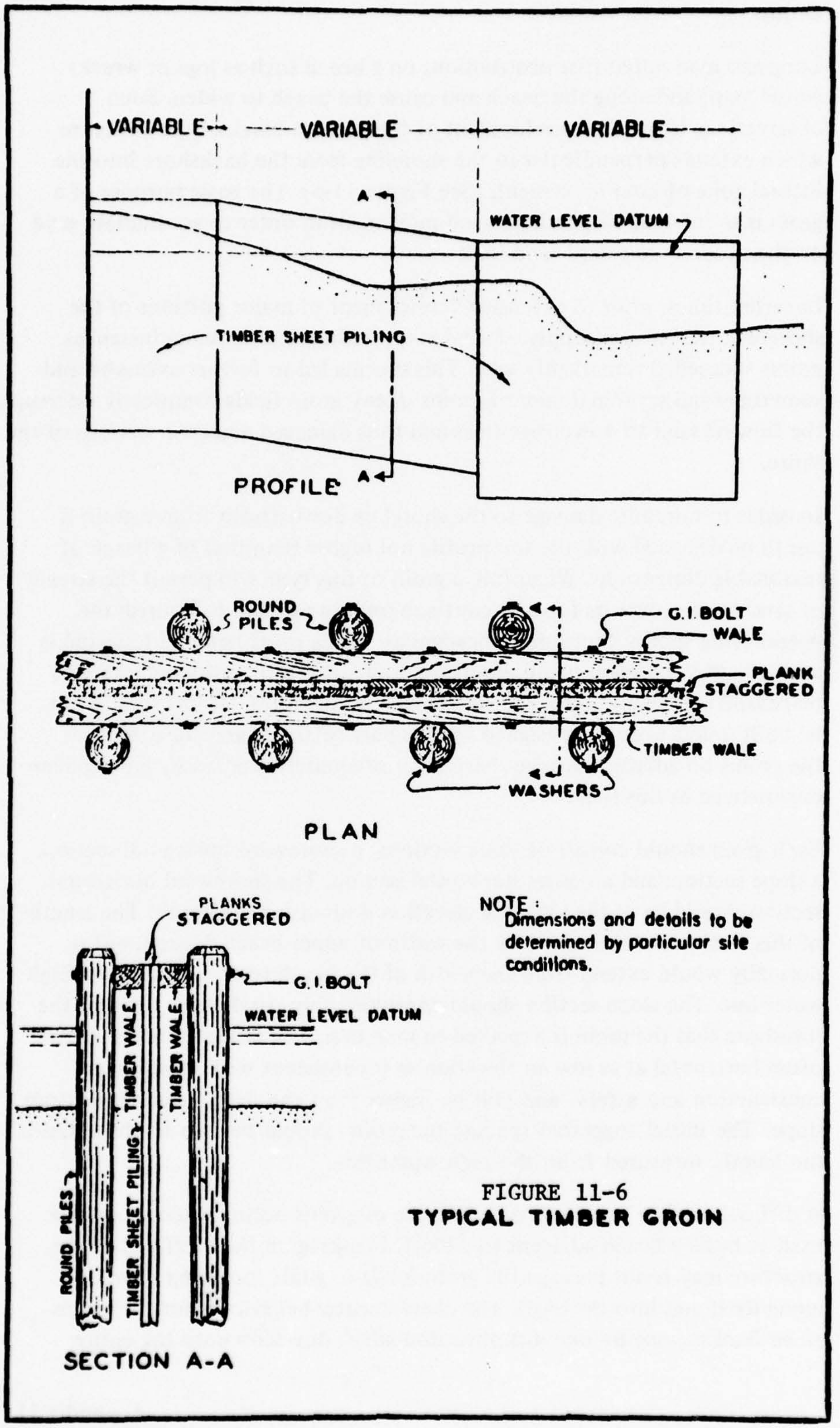


FIGURE 11-6
TYPICAL TIMBER GROIN

system becomes isolated. A solution is to secure the groin into riprap which dissipates the wave energy.

Several types of groin construction have been tried in the Bay with varying degrees of success. The use of rubble mounds to form groins has experienced limited success, but they have a definite advantage in that they are easy to construct and to reform after storm attack. Groins have also been made that consist of hollow concrete rings from 2 to 3 feet in diameter and from 2 to 5 feet in length. These rings are sunk into the beach on end and butted to one another such that their top elevations approximate that which is required for normal groin construction. There is a high failure rate for this type groin due to uneven settlement causing cracks to open between the sections of pipe.

Beach Nourishment

Another structural measure which can be used either singularly or in connection with the aforementioned measures is beach nourishment. Beach nourishment is the addition of sand to an eroding natural beach thereby replacing the material lost to erosion and extending the natural protection provided by the nearshore.

To restore an eroded beach and stabilize it at the restored position, material is placed directly along the eroded sector and additional material is stockpiled at the updrift end of the problem area. The stockpiled material will then maintain the restored portion of the beach. When conditions are suitable for artificial nourishment, long reaches of shore may be protected by this method at a relatively low cost per linear foot of shoreline. An equally important advantage is that artificial nourishment directly remedies the basic cause of most erosion problems – a deficiency in sand supply. This method also benefits the adjacent shoreline and the widened beach has increased recreation value.

NONSTRUCTURAL SOLUTIONS

Nonstructural solutions include the enhancement of natural protective measures and the regulatory actions that can be employed to either control erosion or avoid a land use-erosion conflict. The following paragraphs include a discussion of the broad application of these measures. As noted in the previous discussion of structural solutions, the development of an effective nonstructural program for a specific area also requires careful consideration of the numerous environmental and economic factors related to shoreline erosion.

Marsh Creation

Marshes are one of nature's ways of protecting the shore from wave and wind erosion. The thick marsh vegetation absorbs the energy of waves breaking on it. Marshes act as a buffer not only in prevention of erosion, but also in stabilizing water flows. They absorb and release the water slowly. Marsh plants act as a baffle to slow tidal currents and flood waters and retain silt-clay sediment carried by waves and wind. In periods of low flow, the impermeable silt-clay sediment may also aid in deterring intrusion of salt water into aquifers. In addition to their ability to halt erosion, reduce sedimentation in the Bay proper, and retard saltwater intrusion, the marshes have a major ecological role as a very high producer of living material which serves as an invaluable part of the Bay ecosystem.

The creation of marshes through the selective placement of material in the nearshore zone can thus be beneficial from several viewpoints. Under the right environmental conditions, marsh vegetation will establish naturally or the natural process may be aided by seeding or transplanting native plants such as smooth cordgrass (Spartina alterniflora). However, marsh grass implantation has not been successful in areas experiencing high erosion rates due to wave action. A possible source of material for the creation of marshes is dredged material from channel maintenance and deepening projects. The use of this material would not only serve to provide erosion control and create additional fish and wildlife habitat, but it could help solve the problem of finding acceptable disposal sites for dredged material.

Vegetative Cover

Vegetation along the shoreline and on the adjacent fastland is another natural means of protection against erosion. In addition to improving the ability of the fastland to resist erosion, vegetation can trap wind blown material and thus aid in the formation of a protective dune.

Vegetation as a sole protection against erosion has proven to be unsuccessful except in well protected areas. Its widest application has been its use in conjunction with other structural measures such as bulkheads and groins. It has been used to stabilize backfills of bulkheads, and in combination with groins in the creation and stabilization of beaches. American and European beach grass, Japanese sedge, Spartina patens, and overseeding with coastal panic grass have been used as common vegetative stabilizers.

Regulatory Actions

Land-use regulations can be used to set aside critically eroding reaches for such nonintensive uses as recreation or open space. This action would prohibit development of structures that would be threatened by a rapidly receding shoreline.

A second approach is to adopt building codes which would allow for development in critically eroding areas but that would require the construction of the appropriate erosion control measures. The developer would be required to build a continuous and uniform structure the length of the reach. In an established development, any proposed shoreline protection should ensure that the cumulative protection would be effective in retarding shoreline erosion along the entire reach.

Public Awareness Programs

The potential hazards of shoreline erosion are sometimes not evident to a prospective developer or homeowner. In order instances the hazard may be apparent, but the preventative action taken to avoid the problem is either ill-conceived or constructed. In either case the individual would benefit from additional information relative to shoreline erosion.

To assist local interest with shore erosion problems, the State of Maryland in conjunction with the Baltimore District Corps of Engineers and other federal agencies is developing a manual entitled "Shore Erosion Control". A public awareness program, including such a manual, would serve to advise the public as to the location and severity of shoreline erosion and could also provide information as to the structural and nonstructural measures that could be used to control erosion. The success of a public awareness program that is directed toward "self-help" is highly dependent upon the publicity which it receives. Distribution of information should be supplemented by public meetings to explain the purpose and intent of the program and where further technical advice can be secured.

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CHAPTER V

REQUIRED FUTURE STUDIES

Based on the discussion and analysis of the existing and future shoreline erosion problems included in the previous chapters, it is apparent that a comprehensive Bay-wide erosion management plan is an important facet of any total management plan for Chesapeake Bay. The development of that erosion control plan and the assessment of its impacts on both the Bay and its resources is a considerable undertaking that requires analytical and field studies as well as testing on the Chesapeake Bay Hydraulic Model.

It is important to recognize that a comprehensive erosion control plan must address the problem and the possible solutions on a Bay-wide basis. When considering the Bay as a system, the erosion of one site may well be supplying the material to a beach which is protecting, through natural means, an adjacent shore. Based on this example the total protection of all presently eroding reaches might result in the creation of equally severe problems in other areas. Thus, studies to identify the sources of material, the ultimate fate of eroded material, and the transport interaction are required for the development of a Bay-wide erosion plan.

Other studies that are required to better understand the physical process of shoreline erosion include defining over a period of time what percentage of the erosion is the result of severe storms and what percentage is due to "normal" tide and wave action. Knowledge of the geologic character and the soil composition of the entire Bay shoreline as well as the ability of various soil types to withstand erosion is also necessary for the evaluation of various protective measures. As the rate of erosion is a key factor in both defining problem areas and evaluating possible solutions, periodic monitoring of the land lost to erosion is required to update erosion rates.

Equally important to the development of an erosion control plan is the assessment of the environmental impacts of proposed structural and nonstructural control measures. To aid in environmental assessments, studies are required to better define the impact that structural measures such as bulkheading have on water quality and the Bay biota. Additional research and field testing is also required on the use of marsh creation and vegetative cover as possible erosion control measures.

The Chesapeake Bay Hydraulic Model has the potential to provide some of the physical data that is necessary to evaluate both existing shoreline erosion and the effects of erosion control measures. As noted in earlier chapters, storm surges and tidal currents play a significant role in shoreline erosion. The model can be used to define the elevation and thus the area inundated by various storm surges. As part of this same type of test, the magnitude and direction of tidal currents in the nearshore zone may also be recorded. An understanding of the area that would be inundated and thus subject to erosive forces as well as the associated tidal currents would be extremely valuable in defining areas that would be severely affected by major storms. With the existing conditions defined, the model could then be used to evaluate the physical effects of proposed structural erosion control measures.

Similar to evaluating erosion control structures, the model can also be used to assess the impact, as it relates to erosion, of other structural proposals. Major channel improvements, harbor breakwaters, and large diked disposal areas are just several examples of projects that could be evaluated from the standpoint of their effects on shoreline erosion.

It should be noted that since the model is a fixed-bed, distorted model the actual erosion of the shoreline cannot be duplicated nor can wave action. While erosion itself cannot be portrayed in the model, sediment distribution testing can be accomplished using gilsonite, which is a material used to simulate sediment. This type of testing is used to define the volume distribution of sediment over a specified area after any given period of time. The results of this type of test would be helpful in determining the eventual fate of eroded materials. Regarding the inability of the model to reproduce wave action, storm surge testing as discussed earlier can be supplemented with analytical studies to define the additional wave set up. A more detailed discussion of the capabilities of the hydraulic model and examples of the tests that can be conducted may be found in Appendix 16, Hydraulic Model Testing.

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SHORELINE EROSION

GLOSSARY

accretion:	may be either natural or artificial; Natural accretion is build-up of land, solely by the action of the forces of nature, on a beach, by deposition of waterborne or airborne material. Artificial accretion is a similar build-up of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means. Opposite of Erosion.
artificial nourishment:	the process of replenishing a beach with material (usually sand) obtained from another location.
beach:	the zone of unconsolidated material that extends landward from the mean low waterline - unless otherwise specified - to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation.
breaker:	a wave breaking on a shore, over a reef, etc.
bulkhead:	a structure or partition to retain or prevent sliding of the land; A secondary purpose is to protect the upland against damage from wave action.
cliff:	a high, steep face of rock; a precipice.
coast:	a strip of land of indefinite width (may be several miles) that extends from the shoreline inland to the first major change in terrain features.
coastal area:	the land and sea area bordering the shoreline.
coastal plain:	the plain composed of horizontal or gently sloping strata of fragmented older rock material fronting the coast, and generally representing a strip of sea bottom that has emerged from the sea in recent geologic time.
coastline:	(1) technically, the line that forms the boundary between the Coast and the Shore; (2) commonly, the line that forms the boundary between the land and the water.
crest of wave:	(1) the highest part of a wave; (2) that part of the wave above stillwater level.

current:	**a flow of water.**
deflation:	**the removal of loose material from a beach or the land surface by wind action.**
diurnal:	**having a period or cycle of approximately one Tidal Day.**
downdrift:	**the direction of predominant movement of littoral materials.**
dunes:	**ridges or mounds of loose, windblown material, usually sand.**
duration:	**in wave forecasting, the length of time the wind blows in nearly the same direction over the Fetch (generating area).**
ebb current:	**the tidal current away from shore or down a tidal stream, usually associated with the decrease in the height of the tide.**
ebb tide:	**the period of tide between high water and the succeeding low water; a falling tide.**
erosion:	**the wearing away of land by the action of natural forces; on a beach, the carrying away of beach material by wave action, tidal currents, or by Deflation.**
estuary:	**(1) the part of a river that is affected by tides; (2) the region near a river mouth in which the fresh water of the river mixes with the salt water of the sea.**
fetch:	**the area in which seas are generated by a wind having a rather constant direction and speed; sometimes used synonymously with Fetch Length.**
fetch length:	**the horizontal distance (in the direction of the wind) over which a wind generates Seas or creates a Wind Setup.**
flood current:	**the tidal current toward shore or up a tidal stream, usually associated with the increase in the height of the tide.**
flood tide:	**the period of tide between low water and the succeeding high water; a rising tide.**
fluvial:	**that which is produced by a river.**

groin: a shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

ground water: subsurface water occupying the zone of saturation; in a strict sense, the term is applied only to water below the water table.

hurricane: an intense tropical cyclone in which winds tend to spiral inward toward a core of low pressure, with maximum surface wind velocities that equal or exceed 75 mph (65 knots) for several minutes or longer at some points. Tropical storm is the term applied if maximum winds are less than 75 mph.

hydraulic model: a flow system so operated that the characteristics of another similar system may be predicted. A model is generally a small-scale reproduction of the prototype, but may be larger and/or geometrically distorted.

hydrology: the scientific study of the waters of the earth, especially with relation to the effects of precipitation and evaporation upon the occurrence and character of water in streams, lakes, and on or below the land surface.

intertidal zone: the shore area between high and low tides.

jetty: on open seacoasts, a structure extending into a body of water, and designed to prevent shoaling of a channel by littoral materials, and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river or tidal inlet to help deepen and stabilize a channel.

littoral: of or pertaining to a shore, especially of the sea.

littoral current: any current in the littoral zone caused primarily by wave action, e.g., longshore current.

littoral drift: the sedimentary material moved in the littoral zone under the influence of waves and currents.

littoral transport: the movement of littoral drift in the littoral zone by waves and currents; includes movement parallel (longshore transport) and perpendicular (on-shore transport) to the shore.

littoral zone: in beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the Breaker zone.

longshore current: the littoral current in the Breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

marsh: an area of soft, wet, or periodically inundated land, generally treeless and usually characterized by grasses and other low growth.

mean low water: (MLW) the average height of the low waters over a long period of time.

mean sea level: (MSL) a fixed reference plane determined by the United States Coast and Geodetic Survey. Mean sea level as used herein is based on the latest sea level datum adjustments of 1953, 1955, and 1959, and approximates the average level of the sea for all stages of the tide over a long period of time.

percolation: the process by which water flows through the interstices of a sediment. Specifically, in wave phenomena, the process by which wave action forces water through interstices of the bottom sediment; tends to reduce wave heights.

period of wave: the time for two successive wave crests to pass a fixed point.

revetment: a facing of stone, concrete, etc., built to protect an embankment or shore structure against erosion by wave action or currents.

riprap: a layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also the stone so used.

rubble: rough, irregular fragments of broken rock.

salt marsh: a marsh periodically flooded by salt water.

scour: removal of underwater material by waves and currents, especially at the base or toe of a shore structure.

seas: waves caused by wind at the place and time of observation.

seawall: a structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action.

shore: the narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach.

shoreline: the intersection of a specified plane of water with the shore or beach (e.g., the highwater shoreline would be the intersection of the plane of mean high water with the shore or beach).

storm surge: a rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress. See Wind Setup.

surge, storm: See Storm Surge.

tidal day: the time of the rotation of the earth with respect to the moon, or approximately 24.84 solar hours (24 hours and 50 minutes) or 1.035 times the mean solar day. Also called lunar day.

tidal prism: the total amount of water that flows into a harbor or estuary or out again with movement of the tide, excluding any freshwater flow.

tide: the periodic rising and falling of the water that results from gravitational attraction of the moon and sun and other astronomical bodies acting upon the rotating earth.

tropical disturbance: a cyclonic wind storm of tropical origin with winds less than 39 mph.

tropical storm: a tropical cyclone with maximum winds from 39 to 74 mph.

trough of wave: the lowest part of a wave form between successive crests. Also that part of the wave below stillwater level.

wave: a ridge, deformation, or undulation of the surface of a liquid.

wind setup: (1) the vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water; (2) the difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water; (3) synonymous with Storm Surge. Storm surge is usually reserved for use on the ocean and bodies of water. Wind Setup is usually reserved for use on reservoirs and smaller bodies of water.

wind waves: (1) waves being formed and built up by the wind; (2) loosely, any wave generated by wind.

ATTACHMENT A

HISTORICAL SHORELINE EROSION RATES
FOR
CHESAPEAKE BAY

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TABLE A-1
HISTORICAL SHORELINE EROSION RATES

STATE OF MARYLAND

ANNE ARUNDEL COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Bodkin Point to Mountain Point	5.3	1.7
Persimmon Point to Hackett Point	6.4	2.5
Hackett Point to Mill Creek	2.9	0.8
Possum Point to Greenbury Point	1.5	2.5
Back Creek to 1,400 feet N.W. of Marshy Point	7.1	1.7
Turkey Point to Dutchman Point	3.2	1.7
Curtis Point to Battees Point	6.1	3.3
Broadwater Creek to Cedar Point	2.6	2.5
Rockhold Creek to Anne Arundel-Calvert County line	5.2	3.3
PATAPSCO RIVER		
Hawkins Point to Bodkin Point	9.9	0.8
MAGOTHY RIVER		
North Shore	9.9	0.6
South Shore	7.2	0.4
SEVERN RIVER		
Greenbury Point to Chase Creek	4.6	0.2
Chase Creek to 2,250 feet north of Cedar Point	6.7	0.5
Horn Point to Clements Creek	4.1	0.7
Clements Creek to Herald Harbor	6.5	0.6
SOUTH RIVER		
Marshy Point to Church Creek	8.8	0.4
Church Creek to head of River	5.0	0.2

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
SOUTH RIVER-Continued		
Turkey Point to Larramore Point	9.9	0.6
Larramore Point to head of River	5.9	0.1
RHODES RIVER - TOTALS	5.9	0.6
WEST RIVER - TOTALS	10.4	0.5

TABLE A-1 (con't)

BALTIMORE COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Carroll Point to Brier Point	4.8	1.4
Seneca Creek to Bowley Point	1.6	0.5
Cuckold Point to Shallow Creek	2.9	2.6
PATAPSCO RIVER		
Curtis Creek to Hawkins Point	3.7	0.4
GUNPOWDER RIVER		
Days Coves to Carroll Point including entrance to Bird River	9.6	0.8
MIDDLE RIVER		
Bowley Point to Frog Mortar Creek on north shore and Booby Point to Turkey Point on south shore	5.2	1.1
BACK RIVER		
Booby Point to Witchcoat Point	6.9	0.7
Witchcoat Point to half mile southeast of Northeast Creek	4.8	0.8
Cuckold Point to Stansbury Point	4.5	1.2
Stansbury Point to 3,000 feet above Cheese Creek	4.1	0.4
Dundee and Saltpeter Creeks	8.2	0.8
Seneca Creek	3.6	0.6

TABLE A-1 (con't)

CALVERT COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
From Anne Arundel-Calvert County boundary to 2,300 feet north of Plum Point	6.0	1.3
From 2,300 feet north of Plum Point to Parker Creek	6.3	2.1
Parker Creek to 2,300 feet south of Flag Ponds	7.1	0.8
2,300 feet south of Flag Ponds to Cove Point	6.2	2.5
Cove Point to Drum Point	5.7	0.2
PATUXENT RIVER		
Drum Point to St. Leonards Creek	7.8	0.6
Petersons Point to Wells Cove	13.0	0.6
Battle Creek to Buzzard Island Creek	5.6	0.4
Buzzard Island Creek to Hunting Creek	6.3	0
Hunting Creek to Cocktown Creek	6.0	0.1*
Cocktown Creek to Jones Point	6.4	0.5*
ST. LEONARDS CREEK	2.3	0.3

*Indicates gain rather than loss.

TABLE A-1 (con't)

CAROLINE COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHOPTANK RIVER		
Hunting Creek to 2 1/2 miles N.W. of Skeleton Creek	6.8	0.8
Vicinity of Dover Bridge	6.3	0.7

TABLE A-1 (cont)

CECIL COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Perryville to Carpenter Point	4.1	0.6
Red Point to Turkey Point	6.4	0.9
Wroths Point to Grove Point	5.1	1.7
NORTHEAST RIVER		
Carpenter Point on West shore and Red Point on east shore to 1 mile south of Northeast	11.2	1.6
ELK RIVER-Northwest Shore		
Turkey Point to 1/2 mile southwest of Hylands Point	6.8	0.6
1/2 mile southwest of Hylands Point to Bull Minnow Point	4.1	1.2
Bull Minnow Point to Plum Point	3.7	0.2*
ELK RIVER-Southeast Shore		
Wroths Point to Veazey Cove	6.0	0.5
Town Point to Back Creek	5.6	0.3
Back Creek to Locust Point	4.4	0.3*

*Indicates gain.

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
BOHEMIA RIVER		
Town Point to Manor Creek and Veazey Cove to Little Hack Point	7.4	0.8
SASSAFRAS RIVER		
Grove Point to Cassidy Wharf	5.6	0.7
Back Creek to Hall Creek	4.5	0.5
FURNACE CREEK		
From Stump Point on West, Shallow Hall Point on East upstream to marshy head of River	2.6	0.1

TABLE A-1 (con't)

CHARLES COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
POTOMAC RIVER		
Prince Georges-Charles County Boundary to Pomonkey Point	5.5	0.7
Pomonkey Creek to Deep Point	8.6	0.5
Mattawoman Creek to Goose Bay	4.1	0.5
Goose Bay to Smith Point	7.7	0.6
Smith Point to Riverside	9.1	0.5
Riverside to Windmill Point	8.8	0.0
Windmill Point to 1 3/4 miles south of Popes Creek	5.5	0.4*
3,000 feet north of Potomac Bridge to Neal Sound	10.2	0.2
PORT TOBACCO RIVER	9.6	1.5*
WICOMICO RIVER		
Neal Sound to Dolly Boarman Creek	5.8	0.3
Dolly Boarman Creek to Charles-St. Marys County Line	8.6	0.4
PATUXENT RIVER	4.8	0.5

*Indicates gain.

TABLE A-1 (con't)

DORCHESTER COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Cook Point to Covey Creek	3.1	4.1
Covey Creek to Miles Point (includes Brannock and Trippe Bays)	8.6	0.7
Mills Point to Ragged Point	6.8	5.4
Oyster Cove to the Big Broads	8.1	12.4
Big Broads to Charity Point	2.9	0.0
CHOPTANK RIVER		
Cook Point to Todd Point	9.3	1.5
Todd Point to Chapel Creek	4.1	0.4
Chapel Creek to Lecompte Creek	8.2	1.2
Lecompte Creek to Hambrooks Bar	5.5	1.2
Hambrooks Bar to Whitehall Creek	5.5	0.5
Whitehall Creek to Warwick River	5.9	0.6
Warwick River to Hunting Creek	5.7	0.8
LITTLE CHOPTANK RIVER-North Shore		
Ragged Point to Cedar Point	5.2	0.7
Cedar Point Gaines Creek (includes entrances to Phillips and Beckwich Creeks)	6.2	0.8
LITTLE CHOPTANK RIVER-South Shore		
Oyster Cove to Hopper Point includes Oyster and Cators Caves	8.6	1.8
Travers Cove to Susquehanna Point includes entrances of Slaughter and Parsons Creek	6.2	1.7
Town Point to Gaines Creek	4.6	0.7

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
HONGA RIVER-East Shore		
Keens Point to Windmill Point	15.1	1.0
Windmill Point to Crab Point (west shore of Fox Creek not included)	12.4	1.2
Crab Point to 1,000 feet northwest of Bishops Head Point	8.2	1.1
FISHING BAY-West Shore		
Bishops Head Point to 4,000 feet southeast of Old House Point	9.0	1.1
4,000 feet southeast of Old House Point to Blackwater Point	7.7	2.0
FISHING BAY-East Shore		
Transquaking River to McReadys Point	9.4	1.3
McReadys Point to southwest end of Clay Island	6.4	2.1
NANTICOKE RIVER-West Shore		
Clay Island to Newfoundland Point	11.2	1.7
Newfoundland Point to Penknife Point	7.7	1.1
Penknife Point to vicinity of Vienna	9.3	0.9
FISHING CREEK		
Town Point to north of Church Creek and McKeil Point to 6,100 feet southeast	5.4	0.5
MADISON BAY	5.6	0.7
BROOKS CREEK	10.1	0.7
HUDSON CREEK		
Both sides upstream 3/4 mile	2.5	1.2

TABLE A-1 (con't)

HARFORD COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Havre De Grace to Spesutie Narrows	7.1	(Negligible)
Spesutie Narrows to Old Woman's Gut	4.5	1.3
Old Woman's Gut to 4,200 feet northwest of Abbey Point	7.1	2.4
Lego Point to Rickett Point	5.3	1.3
GUNPOWDER RIVER		
Rickett Point to Maxwell Point	5.9	1.0
Maxwell Point to Foster Branch	5.4	0.4
BUSH RIVER-West Shore		
Lego Point to Lauderick Creek	8.8	0.9
Lauderick Creek to 700 feet west of Bush Point	5.4	0.0
BUSH RIVER-East Shore		
Bush Point to Chilbury Point	5.7	4.9
Chilbury Point to Church Point	4.7	1.0
ROMNEY CREEK		
Measured upstream 1 1/4 miles	3.8	0.3
SPESUTIE NARROWS-West Shore	3.1	1.2

TABLE A-1 (con't)

KENT COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Betterton to Stillpond Creek	5.9	0.7
Stillpond Creek to Tims Creek	7.1	1.4
Worton Creek to Fairlee Creek	3.0	2
Fairlee Creek to 2 miles south of Tolchester Beach	6.3	0.9
2 miles south of Tolchester Beach to Tavern Creek	4.1	2.7
Tavern Creek to Huntingfield Creek	5.4	0.9
Huntingfield Creek to Wilson Point	5.1	2.2
SASSAFRAS RIVER		
Betterton to Kentmore Park	6.0	1.1
Kentmore Park to 3,500 feet east of Old Field Point	5.3	0.4
CHESTER RIVER		
Ringold Point to Cliffs Point	6.3	0.8
Cliffs Point to Melton Point	5.6	0.4
Melton Point to 6,300 feet northwest of Skillet Point	5.8	0.2
From 6,000 feet south of Radcliff Creek to point north of Possum Point	6.3	0.8
EASTERN NECK NARROWS		
Wilson Point to Ringold Point	2.0	0.9

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
GRAYS INN CREEK		
From Little Gum Point to Grays Inn Point upstream 1 mile	2.4	0.4
LANGFORD BAY		
To 1 1/4 miles above mouth	4.6	0.5

TABLE A-1 (con't)

PRINCE GEORGES COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
POTOMAC RIVER		
2,000 feet north of Rosier Bluff to Swan Creek	3.8	0.5
Swan Creek to Charles-Prince Georges County boundary	3.5	0.5
PATUXENT RIVER		
Chalk Point to Black Swamp Creek	7.3	0.2
Milltown Landing to Rock Creek	5.6	0.2
SWANSON CREEK		
From Chalk Point upstream 3/4 mile	1.1	0.0

TABLE A-1 (con't)

QUEENN ANNES COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Love Point to Broad Creek	5.1	3.5
Broad Creek to 3/4 mile south of Craney Creek	5.7	1.7
From 3/4 mile south of Craney Creek to Kent Point	6.8	3.3
CHESTER RIVER		
Love Point to Piney Creek	5.0	1.5
Piney Creek to Jackson Creek	6.0	0.9
Jackson Creek to Tilgham Creek	6.3	1.2
Break Point to Holton Point	4.8	1.1
Corsica River to Shell Point	5.8	0.5
Shell Point to Hambleton Creek	6.2	0.2
Hambleton Creek to 2,200 feet east of Possum Point	7.3	0.2
EASTERN BAY-West Shore		
Kent Point to 4,500 feet north of Romancoke East Shore	6.4	1.7
Hoghole Creek to Bennett Point	6.7	1.3
CRAB ALLEY BAY	7.1	1.2
PROSPECT BAY-West Shore		
Narrow Point to Kent Narrows	7.2	0.4
Kent Narrows to Hoghole Creek	7.5	1.0

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
WYE RIVER-West Shore		
Bennett Point to west of Grapevine Point	5.2	0.2
Brodley Point to 1,500 feet north-east of Grapevine Point	4.7	0.6
WYE EAST RIVER		
Bordley Point to Granary Creek	3.8	0.2
CORSICA RIVER-North Shore		
From entrance to Emory Creek	2.0	0.3
South Shore Holton Point to Corsica Landing	2.9	0.4
REED CREEK		
From entrance upstream 3/4 mile	3.0	0.2
SOUTHEAST CREEK		
From entrance upstream 1/2 mile	1.3	0.9
SHIPPING CREEK	1.3	1.7
COX CREEK		
From south end of Bats Neck on west, Turkey Point on east upstream 1 1/2 miles	4.5	1.0

TABLE A-1 (con't)

ST. MARYS COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Hogg Point to Pine Hill Run	4.5	1.6
Pine Hill Run to shore east of St. James	5.0	1.1
From 4 3/4 miles northwest of Point No Point to Jerome Point	6.6	3.8
Deep Point to Point Lookout	6.4	2.3
POTOMAC RIVER		
White Neck Creek to Flood Creek	9.0	1.7
Flood Creek to McKay Beach	5.1	1.3
McKay Beach to Straits Point	5.7	1.1
Smith Creek to Biscoe Creek	2.8	3.5
Biscoe Creek to Point Lookout	4.8	1.2
PATUXENT RIVER		
Harper Creek to Town Point	5.4	0.0
Town Point to 1 mile northwest of St. Cuthbert Wharf	5.3	0.2
From 1 1/4 miles southeast of Sotterly Point to Cole Creek	5.2	0.3
Cole Creek to Horse Landing Creek	4.8	0.7
Horse Landing Creek to Trent Hall Point	4.3	0.7
Trent Hall Point to Indian Creek including entrance to Trent Hall Creek	3.6	0.4
WICOMICO RIVER		
White Neck Point to Manahowic Creek	5.5	0.2
Manahowic Creek to Budds Creek	6.3	0.3

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
ST. MARYS RIVER-West Shore		
Cherryfield Point to 1,000 feet north of Deep Point	6.3	0.7
East Shore:		
Kitts Point to Church Point including entrance to St. Inigoes Creek	7.9	1.4
ST. CLEMENT BAY		
From 2,000 feet south of St. Patrick Creek on west shore and Cornish Point on east, upstream 1 mile	2.8	0.7
BRENTON BAY		
From Kaywood Point on west shore, Huggins Point on east shore, upstream 1 mile	4.2	0.2
CHAPTICO BAY		
From entrance upstream 1 1/2 miles	3.6	0.0

TABLE A-1 (con't)

SOMERSET COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
TANGIER SOUND		
Lower half of Laws Thorofare to Crab Point	10.4	0.8
St. Pierre Point to Big Annemessex River	13.2	0.7
Flatcap Point to Island Point	7.2	1.7
Great Point to Cedar Island Creek	3.9	2.5
POCOMOKE SOUND		
Watkins Point to Ware Point	8.2	1.4
Ape Hole Creek to Fair Island Canal	8.3	2.2
WICOMICO RIVER		
Wingate Point to Mt. Vernon Wharf	4.1	0.7
NANTICOKE RIVER AND WICOMICO RIVER ENTRANCES AND TANGIER SOUND		
North entrance of Upper Thorofare to Pigeon Creek	6.3	1.8
MONIE BAY		
Wingate Point and Pigeon Creek to Nail Point	6.0	1.5
MANOKIN RIVER		
On north shore, Crab Point to Locust Point, on south shore, St. Pierre Point to Back Creek	8.3	0.7

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
BIG ANNEMESSEX RIVER-North Shore		
Pat Island to Horsehead Point	9.9	0.7
Flatcap Point to Gales Creek	9.0	0.7
LITTLE ANNEMESSEX RIVER		
On north shore from Old House Cove to 1,800 feet northeast of Long Point; on south shore from Great Point to 1,800 feet northeast of Hammock Point	7.0	0.8
APE HOLE CREEK	4.3	1.5
CEDAR STRAITS	2.2	0.6
EAST CREEK		
From entrance upstream 3/4 mile	3.0	0.6
MARUMSCO CREEK		
From 3,100 feet north of Rumbly Point and from the western end of Sound Shore upstream 1/2 mile	1.8	0.5

TABLE A-1 (cont)

TALBOT COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
700 feet east of Wades Point to Harbor Cove	4.3	2.4
Harbor Cove to Knapps Narrows	7.0	2.1
EASTERN BAY		
Wades Point to Tilghman Point	4.3	1.7
CHOPTANK RIVER		
Lucy Point to Benoni Point	2.3	2.9
Bachelor Point to Martin Point	5.2	0.8
La Trappe Creek to Muddy Creek	6.0	0.6
Muddy Creek to Goose Point	5.4	0.7
Goose Point to 6,000 feet northeast of Racoon Creek	4.8	0.5
6,000 feet northeast of Racoon Creek to Windy Hill	4.9	0.3
Windy Hill to 4,700 feet below Parker Creek	4.9	0.4
4,300 feet below Parker Creek to Kingston Landing	4.7	0.0
MILES RIVER-North Shore		
Wyetown Point to Fairview Point	4.2	1.4
Leeds Creek to 3,700 feet above Hunting Creek	3.9	0.8
3,700 feet above Hunting Creek to shoreline east of Unionville	4.7	0.6

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
MILES RIVER-South Shore		
Tilghman Point to Hambleton Point	6.0	1.1
Hambleton Cove to St. Michaels Harbor	2.7	0.7
Parrott Point to Newcomb Creek	4.3	0.8
Newcomb Creek to shore east of Unionville	4.8	0.7
WYE AND WYE EAST RIVERS		
Including Shaw Bay and Lloyd Creek	6.1	0.6
TRED AVON RIVER-West Shore		
Benoni Point to Pecks Point	3.5	0.2
Pecks Point to Double Mills Point	3.4	0.6
Double Mills Point to Shipshead Creek	3.3	0.8
TRED AVON RIVER-East Shore		
Bachelor Point to Trippe Creek, includes Town Creek Flatty Cove and Goldsborough Creek	6.2	0.5
Trippe Creek to 2,000 feet north of Watermelon Point	4.8	0.4
HARRIS CREEK-West Shore		
Knapps Narrows to Smith Point, includes entrance to Dun and Waterhole Coves	5.0	0.9
Briery Cove to Rabbit Point, includes entrance to Cummings Creek	2.2	0.7

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
HARRIS CREEK-East Shore		
Nelson Point to 2,800 feet northeast of Little Neck Point	8.5	2.0
BROAD CREEK		
Nelson Poine to 3,700 feet north of Edgar Cove on west shore	6.8	0.7
Irish Creek to 1 1/3 miles upstream from Church Neck Point includes Bridge Creek, on east shore	8.0	1.2
EDGE CREEK		
From entrance upstream 1 1/2 miles includes Elberts Cove	4.5	0.7
LEADENHAM AND GRACE CREEKS		
Leadenham Creek upstream 6,800 feet and Grace Creek 2,500 feet	6.1	0.6
SAN DOMINGO CREEK		
Upstream 1 1/2 miles	2.7	0.7
TRIPPE CREEK		
Upstream 4,000 feet	2.0	0.3
PEACHBLOSSOM CREEK		
Upstream 2,700 feet	1.4	0.5

TABLE A-1 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
LEEDS CREEK Upstream 2,500 feet	1.0	0.3
IRISH CREEK Upstream 6,400 feet	1.7	0.4
KNAPPS NARROWS North Shore	1.3	0.1*

*Indicates gain.

TABLE A-1 (con't)

WICOMICO COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
NANTICOKE RIVER		
Stump Point to Bivalve	6.7	1.9
Bivalve to southern inlet of Quantico Creek	6.7	1.2
Southern inlet of Quantico Creek to Athaloo Landing	7.4	0.8
Athaloo Landing to Vienna	6.5	1.5
WICOMICO RIVER		
Nanticoke Poine to 1,800 feet northeast of Holland Point	5.2	1.6
From 1,800 feet northeast of Holland Point to New Road Landing	2.5	0.7

TABLE A-2
HISTORICAL SHORELINE EROSION RATES

COMMONWEALTH OF VIRGINIA

ACCOMAK COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Tangier Island Large	15.4	3.9
Tangier Island East Pt. Marsh	2.5	2.0
Goose Island	4.1	2.0
Queen Ridge	0.7	1.3
Little Fox Island	0.5	27.4
Watts Island	4.9	2.9
Smith Gut Spit to VA-MD Line	0.3	32.6
VA-MD Line to Smith Gut Pt. and back	2.7	1.2
Sedge Island	0.6	2.1
Fishing Creek & S. Pt. Marshes	7.4	1.0
Smith Island Back Range VA-MD Line	0.7	2.0
Shanks Island	1.6	13.2
Does Hammock Island	0.2	1.6
Big Ledge Island	0.1	4.6
Green Harbor Island	0.3	1.5
Map Edge to Horse Hammock Gut	0.9	1.3
Horse Hammock Gut Island	0.9	2.5
Pig Pt. to North End Pt.	2.5	3.2
North End Pt.	0.3	+1.2
North End Pt. to Drum Bay	2.4	4.6
Drum Bay to Back Cove	4.4	1.7
Back Cove	1.4	5.5
Back Cove to Back Creek	1.0	1.8
West Mouth Back Creek	0.3	3.4
Messongo Creek to Tims Pt.	7.7	0.9
South Pt. to Cattail Creek	2.6	1.6
Savage Island	3.6	0.9
Savage Island to Backway Gut	0.6	2.5
Backway Gut to Russel Island	2.8	2.0
Scott Island	0.2	2.1
West Marsh Tump	0.1	5.1
Island SW of West Marsh Tump	0.2	5.2
Camp Island	0.2	6.9
Camp Island to Old Beach	2.3	2.2
Island North of Reach Island	0.2	5.5
Sound Reach To Ware Pt.	2.3	5.0
Ware Pt.	0.2	+1.1
Thickett Pt. to Matchotank Creek	0.6	1.9
Parker Islands	3.8	1.8
Finneys Island	5.0	0.9
Scarbourough Island	1.3	1.4
Indian Pt. to Klondike Pt.	2.7	1.5

TABLE A-2 (con't)

Locality	Miles Measured	Erosion Rate Ft/Yr
Pungoteague	10.7	1.1
Bluff Pt. to Butcher Creek Spit	4.0	3.2
Creek East of Hacks Neck Creek to Back Creek	1.2	1.7
Back Creek to Map Edge	0.5	2.0
Milby Pt.	0.4	2.6
Sandy Pt. Spit	0.4	0.9
Craddock Creek	10.1	0.7
Craddock Creek to Poles Bluff	1.9	4.9
Poles Bluff	1.1	+1.1
Occohannock Creek	11.4	0.7

TABLE A-2 (con't)

CHARLES CITY COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHICKAHOMINY RIVER		
Old Neck to Old Neck Creek	3.7	0
Old Neck Creek to Ferry Pt.	7.4	1.1
JAMES RIVER		
Ferry Pt. to Tyler Creek	10.9	.1
Tyler Creek to Weyanoke Creek	3.7	.4
Wetanoke to Queens Creek	4.8	.1
Queens Creek to Eppes Creek	9.0	.4
Eppes Creek to Shallow Shoreline	3.5	.3
Shallow Shoreline to Turkey Island Creek	6.0	.5

TABLE A-2 (con't)

ESSEX COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
RAPPAHANNOCK RIVER		
Blandfield Pt. to Lewis Creek	.9	4.4
Jenkins Landing to Piscataway Creek	9.6	2.3
Piscataway Creek to Lowery Pt.	1.4	1.5
Lowery Pt. to 1/2 mi. South of Eubank	3.8	+.6
1/2 mi. South of Eubank to Essex County Line		

TABLE A-2 (con't)

GLOUCESTER COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY (MOBJACK BAY)		
County Line to Davis Creek	10.4	0.0
Davis Creek to Point opposite Ware River Pt.	7.9	.3
Ware River Pt. to Old House Creek	2.9	2.5
Old House Creek to Turtleneck Pt.	9.5	1.8
Turtleneck Pt. to Long Creek Shoreline	no record	
Long Creek to Browns Baylight	3.2	2.0
Browns Baylight to Shoreline across from Hog Island	11.9	1.3
PIANKATANK RIVER		
Headwaters to Holland Pt.	4.9	.13
YORK RIVER		
Sandy Pt. to East of Perrin River	2.8	1.7
East of Perrin Creek to Aberdeen Creek	18.8	0.7
Aberdeen Creek to Capahosic Area	2.8	1.2
Capahosic Area to Morris Bay	7.0	0.9

TABLE A-2 (con't)

CITY OF HAMPTON

Locality	Miles Measured	Erosion Rate Ft/Yr
BACK RIVER		
Harris Creek to Northend Pt.	2.9	1.9
CHESAPEAKE BAY		
Northend Pt. to Old Point Comfort	8.5	4.5
JAMES RIVER		
Old Point Comfort to City Limits	3.2	2.1

TABLE A-2 (con't)

ISLE OF WIGHT COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
JAMES RIVER		
Lawnes Creek to Days Pt.	9.1	1.0
Days Pt. to Williams Creek	7.7	3.4
Goodwin Pt. to Ballard Marsh Pt.	0.8	1.1
Ballard Marsh Pt. to Ragged Island	7.2	1.9
Ragged Island Creek to Chuckatuch Creek	1.1	1.2

TABLE A-2 (con't)

JAMES CITY COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
YORK RIVER		
Ware Creek to Skimino Creek	7.9	1.7
JAMES RIVER		
Skiffes Creek to The Thorofare	9.6	.2
The Thorofare to Barrets Pt.	0.3	1.4
CHICKAHOMINY RIVER		
James River to Shields Pt.	6.4	0.9
Shield Pt. to Headwater	3.7	1.3

TABLE A-2 (con't)

KING GEORGE COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
POTOMAC RIVER		
Metomkin Pt. to Choptank Creek	1.7	2.2
Choptank Creek to Mathias Pt.	6.2	1.2

TABLE A-2 (con't)

KING & QUEEN COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
YORK RIVER		
Roane to Brooks Creek	4.1	1.1

TABLE A-2 (con't)

LANCASTER COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
CHESAPEAKE BAY		
Indian Creek to Tabbs	1.4	6.4
Tabbs Creek to Windmill Pt.	4.9	7.5
RAPPAHANNOCK RIVER		
Windmill Pt. to Westland Shore Area	1.0	3.7
Westland Shore Area West 6.6 mi.	6.6	+0.5
From Pt. 6.6 mi. West of Westland Shore Area to Mosquito Creek	3.8	0.7
Mosquito Creek to Mosquito Pt.	1.2	0.3
Mosquito Pt. to Wharton Lagoon	4.8	1.4
CORROTOMAN RIVER		
Eastern Shoreline	4.0	2.7
Western Shoreline	3.0	1.5
RAPPAHANNOCK RIVER (cont'd)		
Towlas Pt.	0.9	0.0
Towlas Pt. to Wyatt Creek	1.1	1.3
Wyatt Creek to Greenvale Creek	3.1	2.6
Greenvale Creek to North of Navy Aux. Air Field	3.4	1.5
North of Navy Aux. Air Field to Deep Creek	.4	2.5
Deep Creek to Mulberry Creek	2.3	2.5
Mulberry Creek to Curletts Pt.	1.4	3.7

TABLE A-2 (con't)

MATTHEWS COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
PIANKATANK RIVER		
Cherry Pt. to Queens Creek	3.0	1.7
Queens Creek to Iron Point	4.5	2.6
Iron Pt. to Holland Pt.	2.9	.4
CHESAPEAKE BAY		
Cherry Pt. to Gwynn Island Sandy Pt.	4.2	5.8
Sandy Pt. to Lanes Creek	3.8	0.5
Lanes Creek to Rigby Island	6.3	2.0
Rigby Island to Winter Harbor Cove	2.5	4.6
Marsh Island to Horn Harbor	5.1	.9
Horn Harbor to Davis Creek	7.1	.8
MOBJACK BAY		
Davis Creek to Diggs Creek	8.4	1.1
Diggs Creek to Roys Point	5.8	1.4
Roys Point to County Line	4.5	.8

TABLE A-2 (con't)

MIDDLESEX COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
RAPPAHANNOCK RIVER		
Essex County Line to Mud Creek	.9	6.5
Mud Creek to Parrots Creek	1.4	.5
Parrots Creek to Smoky Pt.	1.5	2.2
Smoky Pt. to Lagrange Creek	3.4	1.7
Lagrange Creek to Urbana Creek	3.1	2.7
Urbana Creek to Cooper	7.1	1.5
Cooper to Grey Pt.		0.0
Grey Pt. to Locklies Creek	3.4	.4
Locklies Creek to Woods Creek	6.1	1.5
Woods Creek to Stingray Pt.	5.3	4.1
PIANKATANK RIVER		
Stingray Pt. to Jackson Creek	.9	2.4
Jackson Creek to Fishing Pt.		0.0
Fishing Pt. to 1/2 mi. West of Bland Pt.	1.0	1.5
1/2 mi. West of Bland Pt. to Headwaters	5.5	1.2

TABLE A-2 (con't)

NEW KENT COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
YORK RIVER		
Bridge to Ferry Creek	1.2	0.6
Ferry Creek to Ware Creek	5.0	1.4

TABLE A-2 (con't)

CITY OF NEWPORT NEWS

Locality	Miles Measured	Erosion Rate Ft/Yr
JAMES RIVER		
James River Bridge to Waters Creek	.5	.7
Waters Creek to Deep Creek Shoreline	4.9	1.1
Western Shoreline of Warwick River	3.1	1.1
Jail Pt. to Nells Creek	1.7	2.0
Nells Creek to Marshy Pt.	2.6	1.1
Eustis Shoreline to Mouth Bailey Creek	4.3	1.4

TABLE A-2 (con't)

CITY OF NORFOLK

Locality	Miles Measured	Erosion Rate Ft/Yr
SOUTHERN CHESAPEAKE BAY		
Willoughby Spit	4.4	0.0
Willoughby Spit East to City Limits	4.9	1.4

TABLE A-2 (con't)

NORTHHAMPTON COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
Sparrow Pt. Creek to S. Area	0.7	4.0
Creek South of Sparrow Pt. to Nassawadox Pt.	4.0	5.1
Shooting Pt. to Westerhouse Creek	1.1	2.3
Westerhouse Creek to 1/2 mi. South	0.6	1.7
1/2 mi. South Westerhouse Creek	0.3	+1.6
Area to Church Neck S1	0.8	0.7
Deposition Area near Church Neck	0.3	+1.4
Church Neck to Hungar Creek	1.8	1.8
Honeymoon Isle Spit	0.7	3.0
Herring Cliff	0.6	+3.9
Windmill Tower to Lat. 37°20'	3.2	5.1
Lat. 37°19' to Westcott Pt. Spit	1.1	3.2
Wescott Pt. Spit	1.7	+2.2
Old Westcott Pt. Spit to Cherry Stone Inlet	1.9	1.8
Mill Creek to Lagoon North of Kings Creek	1.3	2.2
South Cape Charles Harbor to 3/4 mi. South	0.7	+7.6
3/4 mi. South Cape Charles Harbor to Old Plantation Creek	1.7	2.4
Old Plantation Creek to Map Edge	3.1	2.3

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CHESAPEAKE BAY FUTURE CONDITIONS REPORT. VOLUME 8. NAVIGATION, --ETC(U)
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TABLE A-2 (con't)

NORTHUMBERLAND COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
POTOMAC RIVER		
Wilkens Creek to Mundy Creek	.4	2.3
Mundy Creek to Cornish Creek	7.9	0.0
Cornish Creek to Thicket Pt.	2.2	2.8
Rt. 680 to Cherry Pt. Neck	1.0	2.7
Cherry Pt. to Travis Pt.	7.2	0.0
Travis Pt. to King Scote Creek	.7	3.0
King Scote Creek to 1 mi. West of Blebe Mouth	9.1	0.0
Honest Pt. to Balls Creek	1.1	2.7
Balls Creek to Ginny Beach	12.2	5.0
LITTLE WICOMICO RIVER		
Ginny Beach to Tabs Creek	30.0	0.0
CHESAPEAKE BAY		
Smith Pt. to Rock Hole	.9	2.6
Rock Hole South .6 mi.	.6	1.2
Chesapeake Beach	3.3	6.1
Taskmers Creek to Cockrell Creek	2.0	2.9
Cockrell Creek to Reason Creek	1.3	2.7
Reason Creek to Whays Creek	5.5	2.6
Whays Creek to Warehouse Creek	1.4	2.1
Penny Creek to Shell Creek	.5	1.3
Shell Creek to Little Sandy Point	2.0	1.5
Bussel Point to Harveys Creek	2.6	1.3
Harveys Creek to Mill Creek	.4	2.4
Mill Creek to Loverdale Creek	5.7	0.0
Ball Creek to Dividing Creek	3.4	1.8
Dividing Creek to Jarvis Creek	4.7	.1
Jarvis Creek to Bluff Pt.	2.4	5.2
Bluff Pt. to County Line	10.0	0.0
WICOMICO RIVER		
Collins Pt. to Horn Harbor	1.4	1.1
Horn Harbor to Coles Creek	2.6	.2
Cole Creek to Tipers Creek	3.0	.9
Tipers Creek to Barrett Creek	5.2	.1

TABLE A-2 (con't)

PRINCE GEORGE COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
JAMES RIVER		
Southern Limit of Hopewell to Gravelly Run	3.3	0.3
Gravelly Run to Chappell Creek	4.9	1.3
Chappell Creek to Windmill Pt.	7.4	1.3
Windmill Pt. to Wards Creek	2.1	1.0
Wards Creek to Road 7	2.9	0.1
Road 7 to Marsh Pt.	2.0	1.2
Marsh Pt. to & Inclu. Upper Chippokes Creek	6.8	1.2

TABLE A-2 (con't)

RICHMOND COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
RAPPAHANNOCK RIVER		
Pearson Island (Lancaster Creek)	.3	3.7
Midway from Morattico Creek to Tarpley Pt.	.4	1.8
Tarpley Pt. to Sharps Rd. Pt.	4.0	1.8
Sharps Rd. Pt. to Richardson Creek	3.7	2.0
Richardson Creek to Waverley Pt.	0.6	.5
Waverley Pt. to McGuire Creek	5.5	2.6
McGuire Creek to Lee Creek	1.7	1.4
Lee Creek to Cat Point Creek	2.0	2.9
Cat Point Creek to County Line	3.9	.3

TABLE A-2 (con't)

SURRY COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
JAMES RIVER		
Prince George County Upper Chippokes Creek to Sunken Meadow Branch	4.4	0.5
Sunken Meadow Branch to Road 4	3.8	11.8
Road 4 to Swann Point	4.3	1.0
Pleasant Pt. to Micilvane	7.4	0.8
Micilvane Bm to Lawnes Creek	6.7	1.9

TABLE A-2 (con't)

CITY OF VIRGINIA BEACH

Locality	Miles Measured	Erosion Rate Ft/Yr
SOUTHERN CHESAPEAKE BAY		
City Limit - East 1.0 mi.	1.0	+.5
1 mi. East of City Limit to Lynnhaven Inlet	3.9	4.4
Lynnhaven Inlet to Fort Story	3.3	+2.9
Fort Story to Cape Henry	2.1	4.5

TABLE A-2 (con't)

WESTMORELAND COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
POTOMAC RIVER		
King George - Westmoreland to Paynes Pt.	4.7	.7
Church Pt. to Stratford Cliffs	5.1	3.5
Stratford Cliffs to Mt. Airy	3.0	.7
Mt. Airy to Cold Harbor Creek	1.4	0.0
Cold Harbor Creek to Matthews Pt.	3.0	.6
Matthews Pt. to White Point	5.8	0.0
White Point to Glebe Creek	4.6	1.3
Glebe Creek to Ragged Point	2.8	3.6
Ragged Point to Lynch Point	9.5	2.7

TABLE A-2 (con't)

YORK COUNTY

Locality	Miles Measured	Erosion Rate Ft/Yr
YORK RIVER		
Skimino Creek to Bigler Mill Pt.	1.4	2.4
Bigler Mill Pt. to Queen Creek	2.4	1.1
Queen Creek to York River Cliffs	14.2	0.7
York River Cliffs to Wormley Creek	4.4	1.1
Wormley Creek to Sandbox	2.7	3.5
CHESAPEAKE BAY		
Sandbox to York Point	4.1	2.8
York Pt. to a nameless Creek	3.3	0.7
Nameless Creek to Quarter March Creek		1.4
Quarter March Creek to Moores Creek	4.9	1.7
Moores Creek to Bay Point	4.0	2.2

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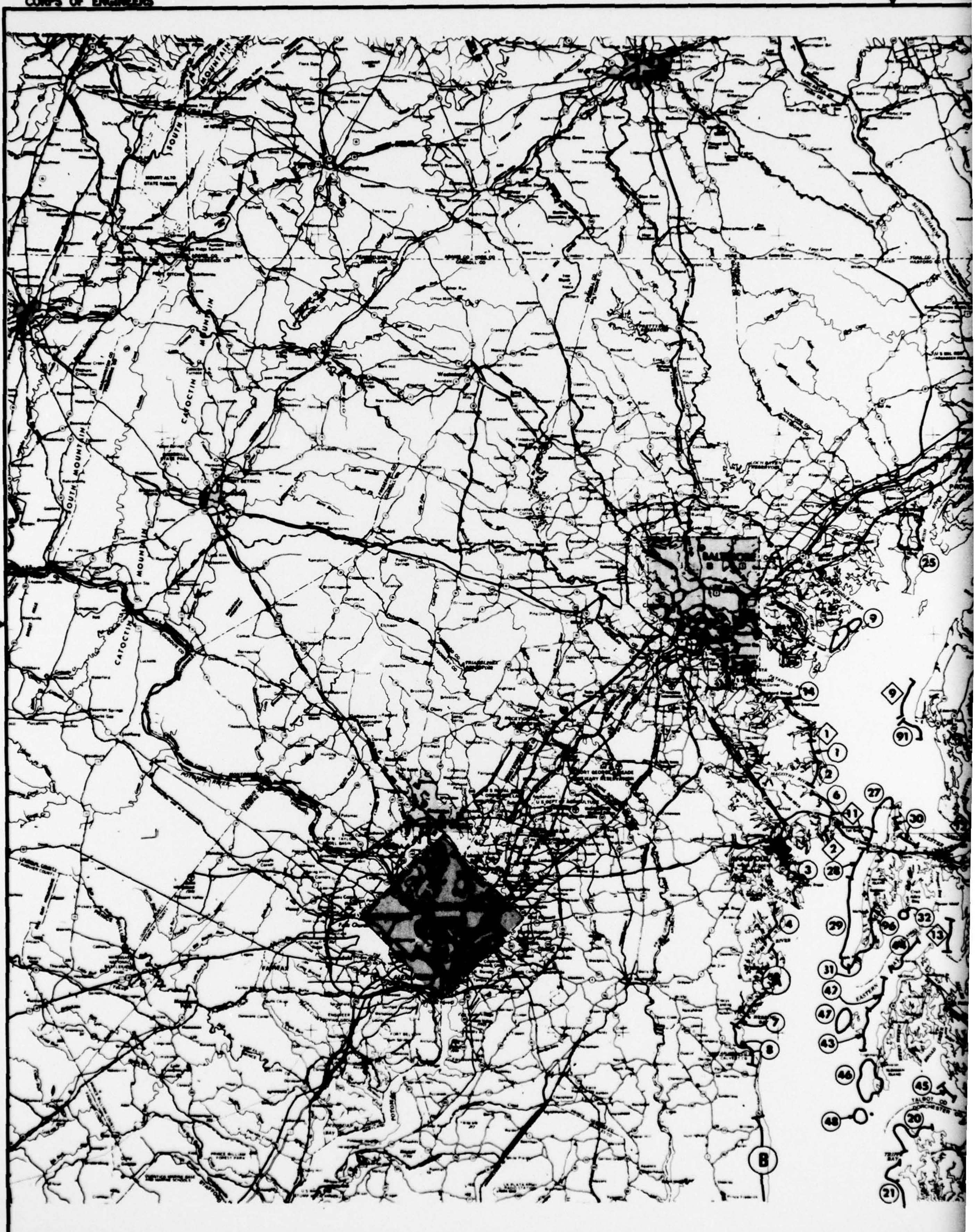

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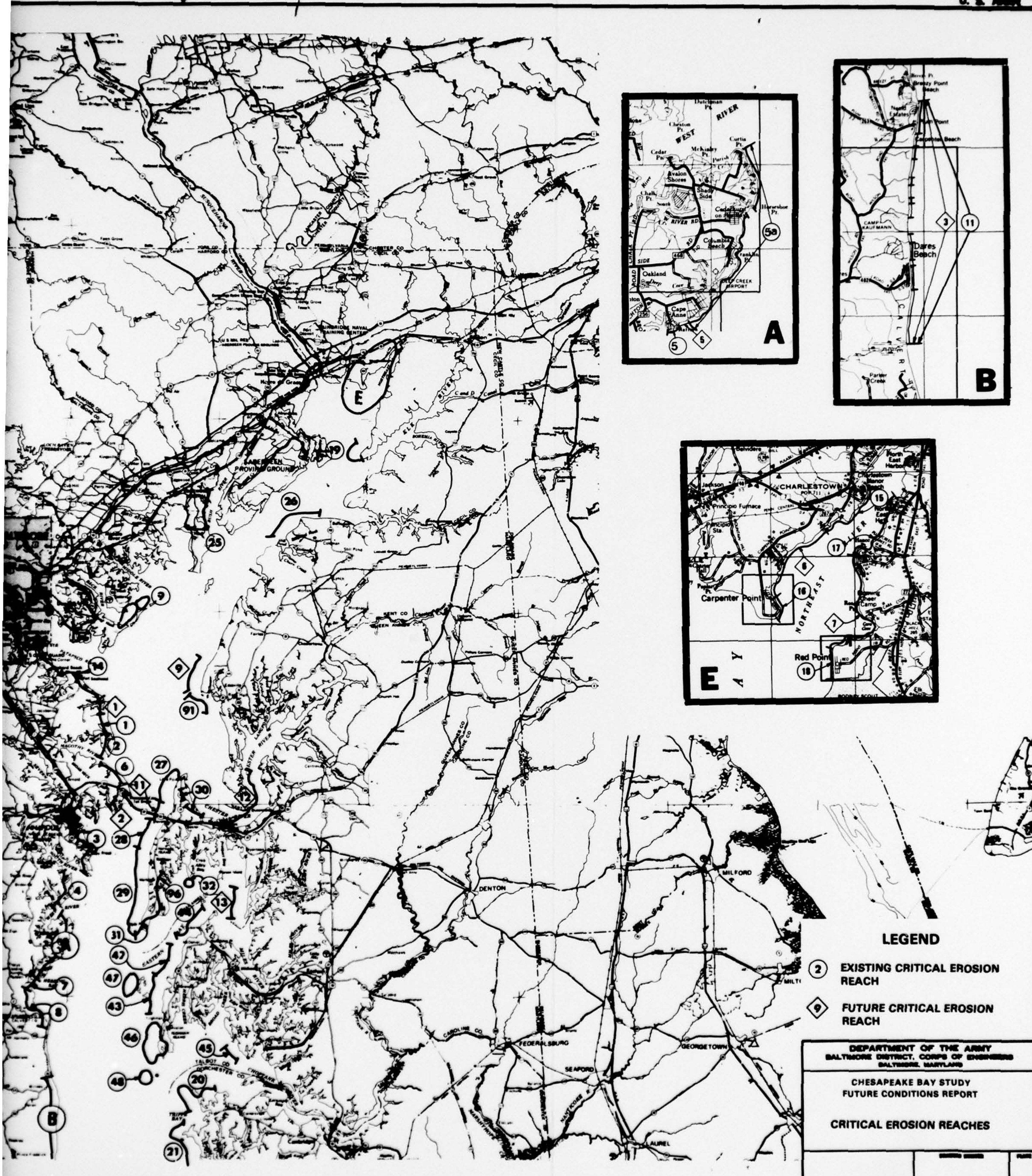

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② EXISTING CRITICAL EROSION REACH

◇ FUTURE CRITICAL EROSION REACH

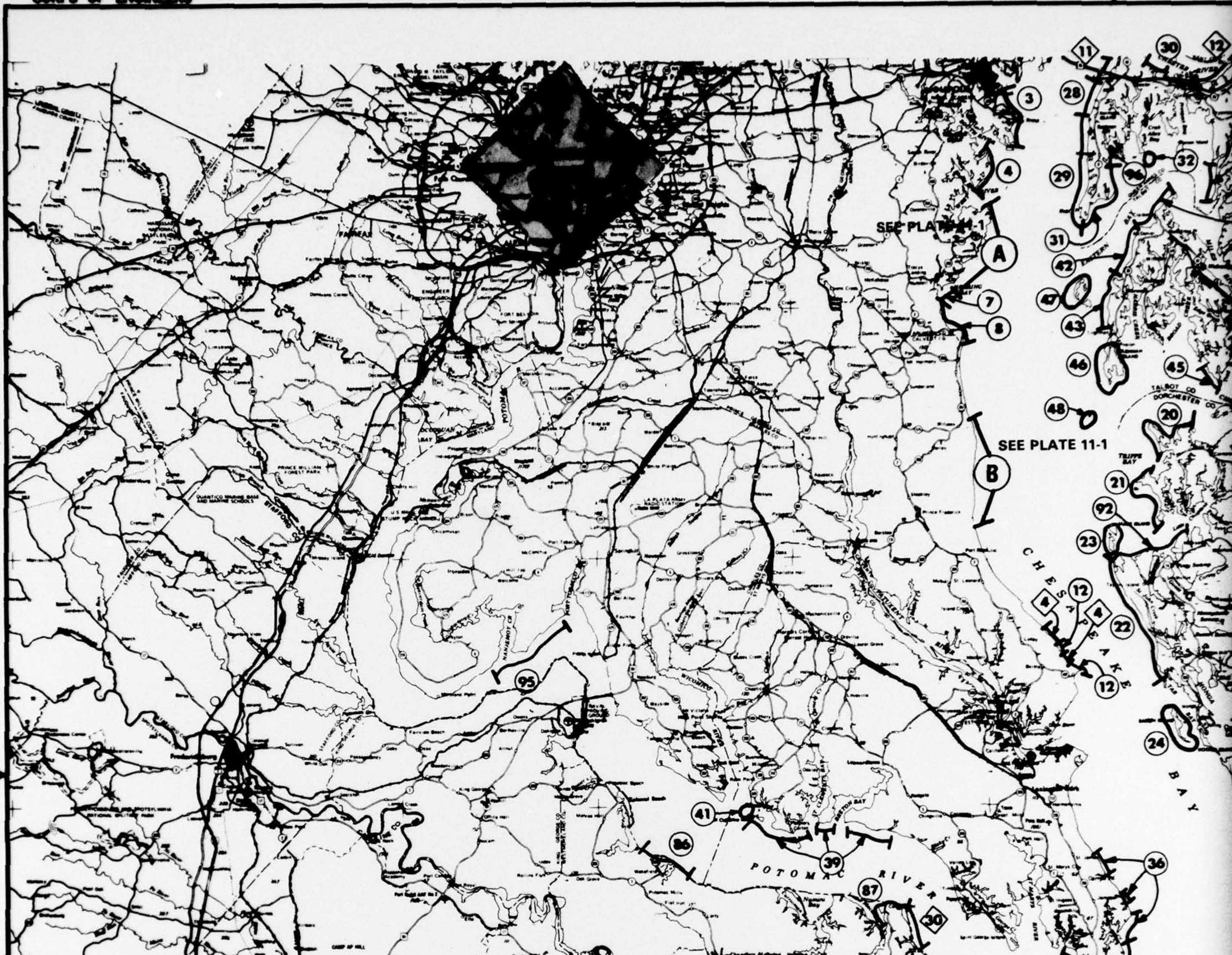
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

CHESAPEAKE BAY STUDY
FUTURE CONDITIONS REPORT

CRITICAL EROSION REACHES

PLATE 11-1

CORPS OF ENGINEERS



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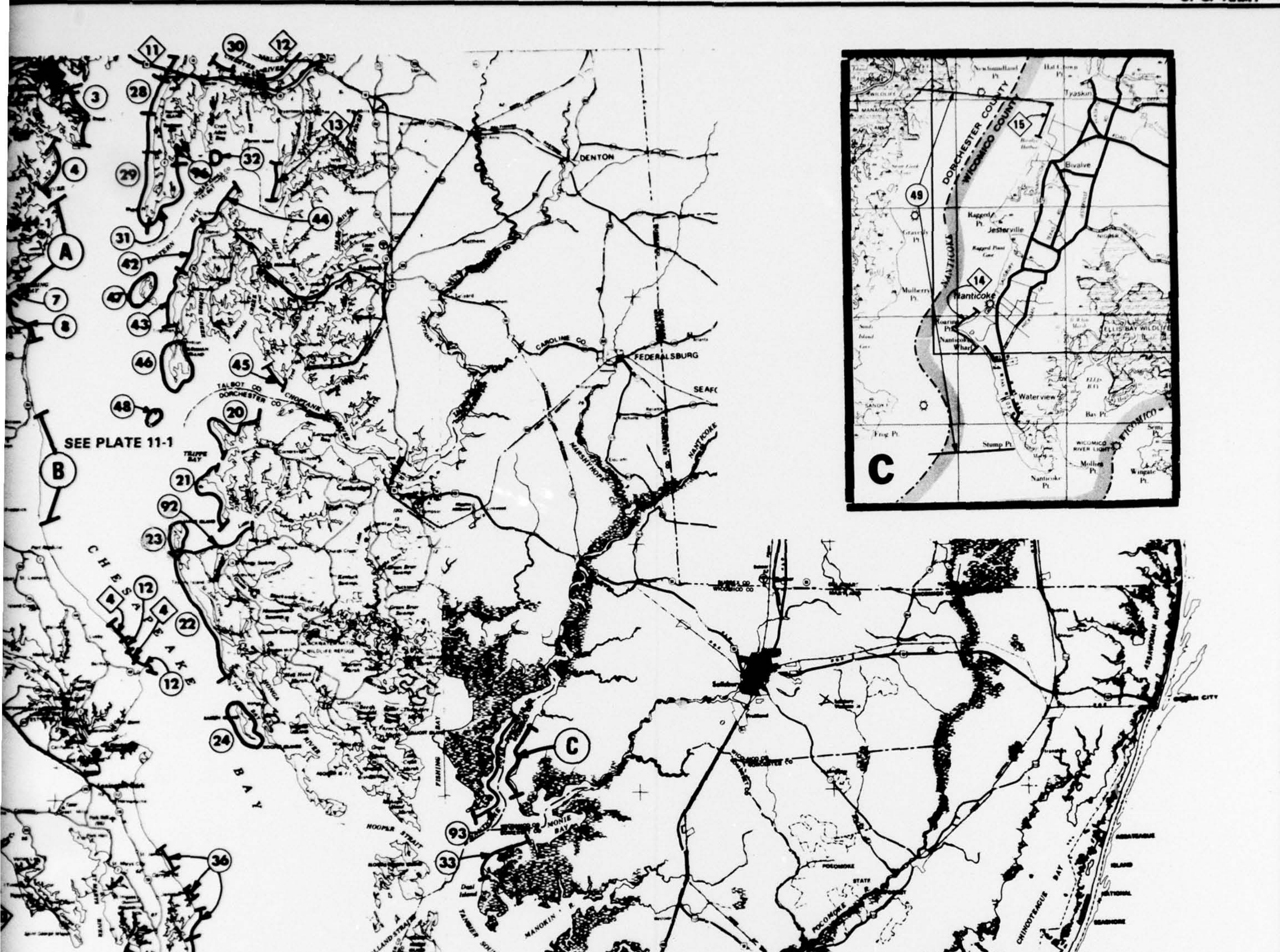

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(2) EXISTING CRITICAL EROSION REACH

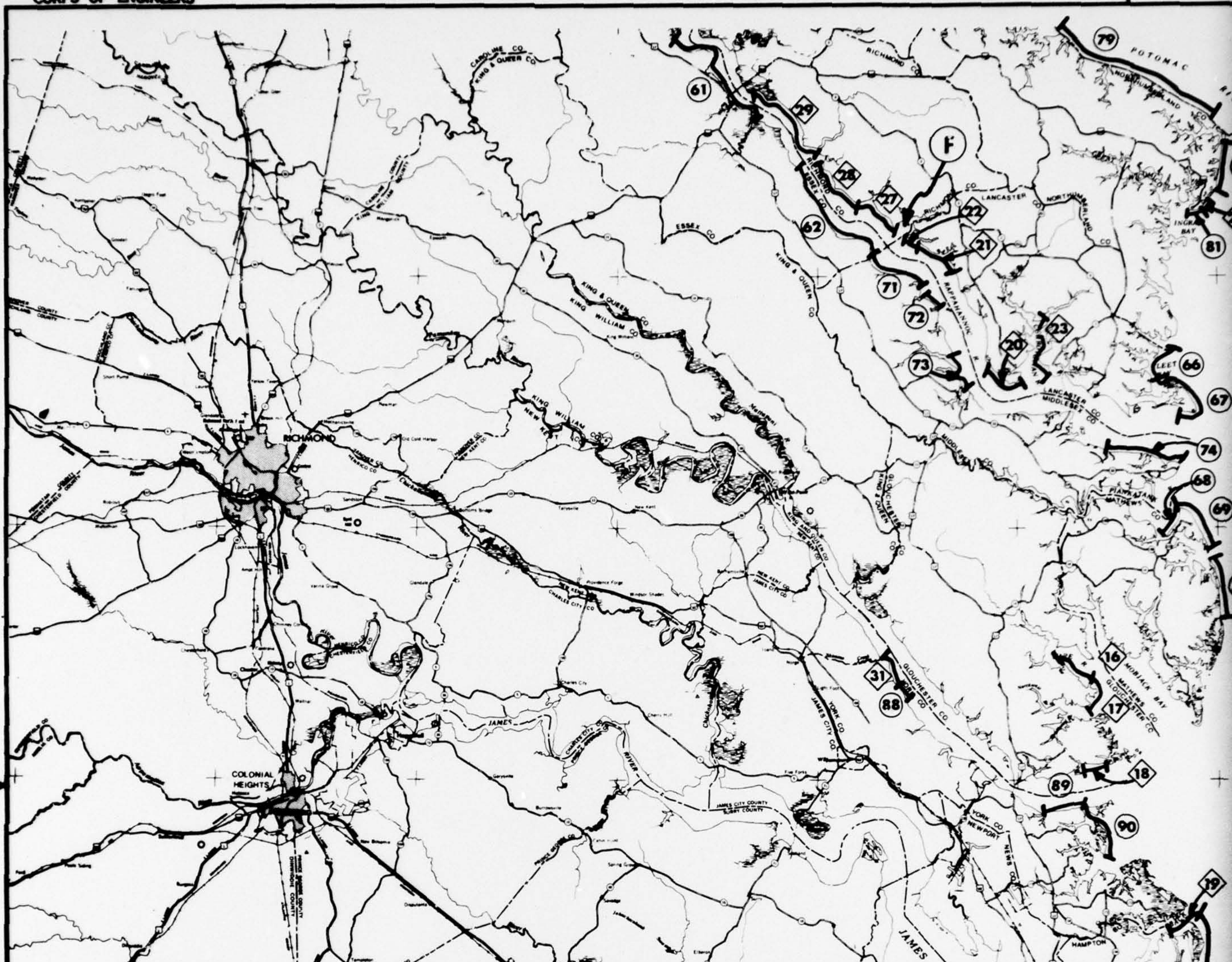
◇9 FUTURE CRITICAL EROSION REACH

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

CHESAPEAKE BAY STUDY
FUTURE CONDITIONS REPORT

CRITICAL EROSION REACHES

PLATE 11-2


RICHMOND
COLONIAL HEIGHTS
HAMPTON
JAMES RIVER
POTOMAC
ESSEX CO
KING & QUEEN CO
KING WILLIAM CO
LANCASTER
MIDDLESEX CO
GLOUCESTER CO
YORK CO
JAMES CITY CO
NEW KENT CO
CHARLES CITY CO
PRINCE GEORGE COUNTY
MOBJACK BAY
DISMAL SWAMP
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LEGEND

(2) EXISTING CRITICAL EROSION REACH

<9> FUTURE CRITICAL EROSION REACH

DEPARTMENT OF THE ARMY
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CHESAPEAKE BAY STUDY
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CRITICAL EROSION REACHES

PLATE 11-3

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